Missouri Department of Natural Resources Water Protection Program

Total Maximum Daily Load (TMDL)

for

Muddy Creek
Grundy and Mercer Counties, Missouri

DRAFT

DRAFT Total Maximum Daily Load (TMDL)
For Muddy Creek
Pollutant: Unknown

Name: Muddy Creek

Location: Near Trenton in Grundy and Mercer Counties, Missouri

Hydrologic Unit Code: 10280102

Water Body Identification: 0557

Missouri Stream Class: P [1]

Designated Beneficial Uses:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B
- Secondary Contact Recreation

Location of Impaired Segment: Sec. 16, T60N, R24W to Section 22, T66N, R23W

Length of Impaired Segment: 42.0 miles[2]

Use that is impaired: Protection of Warm Water Aquatic Life

Pollutant: Unknown

TMDL Priority Ranking: High

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[1] Class P streams maintain permanent flow even during drought conditions. See Missouri water quality standards 10 Code of State Regulations [CSR] 20-7.031(1)(F)4. The water quality standards can be found at: www.sos.mo.gov/adrules/csr/current/10csr/10c20-7.pdf

[2] Listed as impaired on the 2008 303(d) List for the full classified water body length of 36.5 miles. Length of water body segment is revised in 10 CSR 20-7.031 Table H to 42.0 miles, effective October 2009. This revision reflects a more accurate measurement of length. The location and the starting and ending points of this segment have not changed. Revisions to 10 CSR 20-7.031 have not been approved by the U.S. Environmental Protection Agency at the time of TMDL submittal.

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1 Introduction

The Muddy Creek Total Maximum Daily Load, or TMDL, is being established in accordance with Section 303(d) of the federal Clean Water Act. This water quality limited segment near Trenton in Grundy and Mercer counties, Missouri is included on the U.S. Environmental Protection Agency, or EPA, approved Missouri 2008 303(d) List of impaired waters.

The purpose of a TMDL is to determine the pollutant loading that a water body can assimilate without exceeding the water quality standards for that pollutant. Water quality standards are benchmarks used to assess the quality of rivers and lakes. The TMDL also establishes the pollutant load capacity necessary to meet Missouri water quality standards based on the relationship between pollutant sources and instream water quality conditions. The TMDL consists of a wasteload allocation, a load allocation and a margin of safety. The wasteload allocation is the portion of the allowable pollutant load that is allocated to point sources. The load allocation is the portion of the allowable pollutant load that is allocated to nonpoint sources. The margin of safety accounts for the uncertainty associated with water quality model assumptions and data limitations.

Muddy Creek was first placed on Missouri's 303(d) List of impaired waters by EPA in 2002 for unknown pollutants, with the source of the impairment unidentified. The basis for the listing was a 2000 visual/benthic low-flow survey conducted on Muddy Creek in Mercer County by the Missouri Department of Natural Resources and included in the Department's "Monitoring Report on 26 Waters" (MDNR 2000). The report concluded that overall biological diversity appeared to be reduced. Evidence of this impairment was primarily narrative rather than numeric, and was based on visual observations of aquatic fauna and stream habitat at three sites in Mercer County.

A Biological Assessment and Habitat Study was conducted in 2006 and 2007 by the Department to provide a more thorough assessment of whether or not the aquatic macroinvertebrate community of Muddy Creek is impaired, and to define the habitat and water quality characteristics of the stream. This study did not reveal any overall water quality impairment and the biological assessment failed to indicate impairment of the macroinvertebrate community (MDNR 2007).

Based on the lack of impairment noted in the biological assessment report, the Department has attempted to have Muddy Creek removed from both the 2004/2006 and the 2008 303(d) Lists. However, EPA has restored Muddy Creek to the List on both occasions. In the administrative record supporting EPA's January 16, 2009 decision on Missouri's 2004/2006 303(d) List, the agency supports this decision by noting that "there is a significant difference in the biology of the aquatic community downstream of the Trenton WWTP" and that "nutrient data indicate conditions persist that could lead to excess algal growth" (EPA 2009). The same rationale was used to restore Muddy Creek to the 2008 303(d) List.

2 Background

This section of the report provides information on Muddy Creek and its watershed.

2.1 The Setting

The headwaters that form Muddy Creek – Irwin Creek and Little Muddy Creek – originate in Wayne County in southern Iowa and flow south into Mercer County, Mo. Once in Missouri, these two water bodies join to form Muddy Creek. Muddy Creek flows south for 42 miles into Grundy County where it joins the Thompson River just south of the city of Trenton. Muddy Creek drains a narrow, north-south oriented watershed of 122.2 square miles in the former prairie region of the state. It is comprised of 109.3 square miles (89.4%) in Missouri and 12.9 square miles (10.6%) in Iowa (Figure 1).

The impaired length of Muddy Creek is 42 miles (see footnote 2), the full length of the classified segment. The classified segment corresponds to that portion of the stream defined in Missouri's water quality standards (10 CSR 20-7.031 Table H); the impaired segment corresponds to that portion of the stream determined to not be meeting water quality standards. In this case they are the same length (Missouri Secretary of State 2008).

2.2 Population

Based on spatial analysis by the Department using 2000 Census Data, the total population of the entire Muddy Creek watershed is approximately 5,027 (U.S. Census Bureau, 2001a). The Missouri portion of the watershed has a population of 4,950, with the remaining population of 77 people being in Iowa. The overall population in the watershed is predominantly urban. The western boundary of the watershed bisects three towns in Missouri: South Lineville, population 37, Mercer, population 342 and Trenton, population 6,216 (Figure 1) (U.S. Census Bureau 2001b). Based on the proportion of the incorporated areas of these towns that fall within the watershed, the urban population in Missouri is estimated to be 3,900, with a rural population of 1,050. In Iowa, the watershed boundary bisects two towns, Lineville and Clio, with populations of 273 and 91, respectively (U.S. Census Bureau 2001b).

2.3 Geology, Physiography and Soils

The Muddy Creek watershed falls within the Loess Flats and Till Plains ecoregion of the Central Irregular Plains. This region has been glaciated and is characterized by low hills and smooth glacial plains. Overall topography ranges from flat to moderately hilly, with slopes generally less than 10 percent and elevations within the Missouri portion of the watershed ranging from 722 to 1,100 feet. Potential natural vegetation is a mix of little bluestem-side oats grama prairie and oak woodlands. The entire region is dominated by Pennsylvanian-age bedrock of sandstone, limestone and shale overlain by loess with loam and clay loam till (Chapman, et al. 2002).

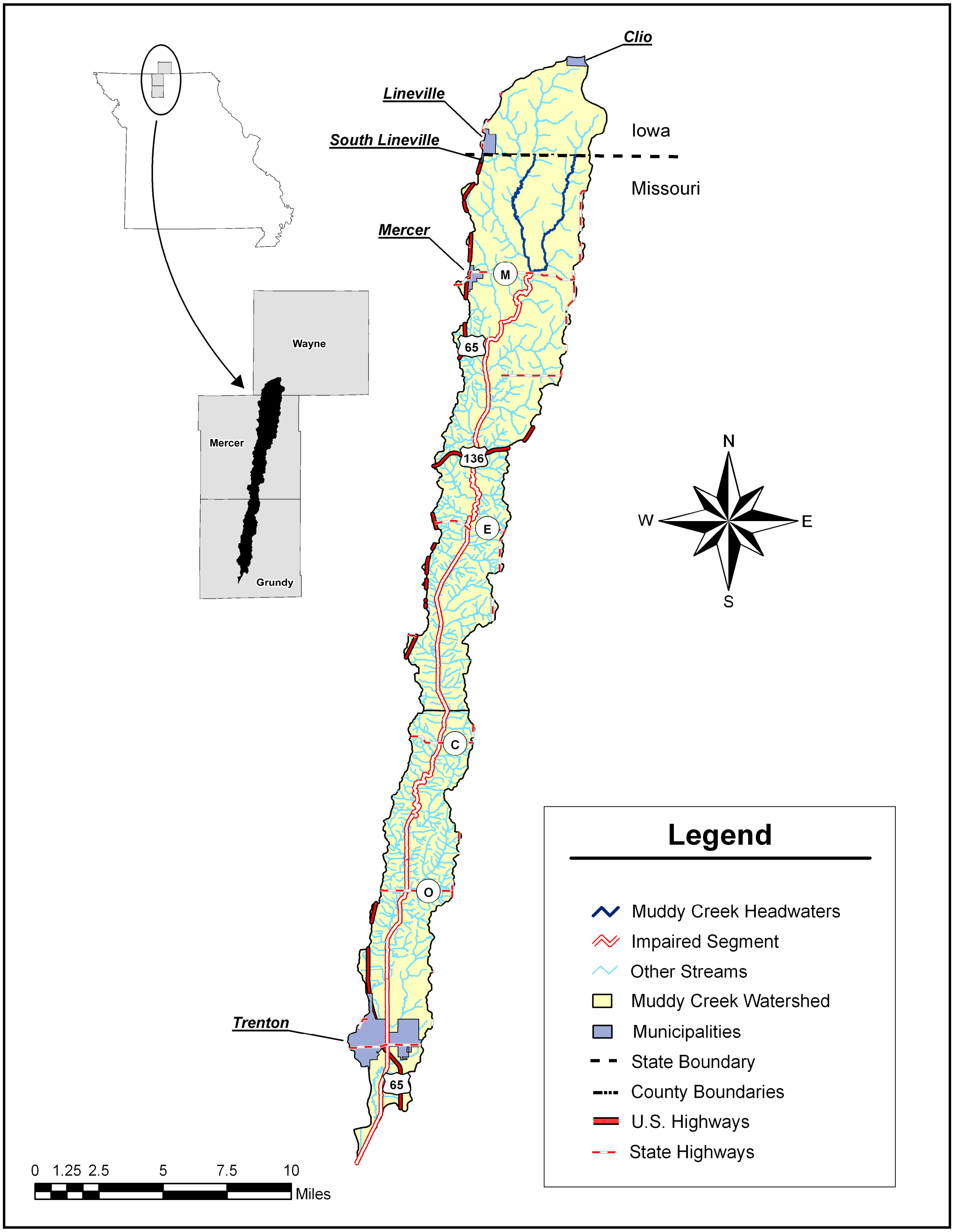

Figure 1. Location of the Muddy Creek watershed

The Soil Survey Geographic database developed by the United States Department of Agriculture Natural Resources Conservation Service, or NRCS, shows that at least 87 percent of the soils in the Muddy Creek watershed in Missouri are characterized as having slow or very slow infiltration rates, and much of the upland area (not in the floodplain) is considered highly erodible or potentially highly erodible. Soil groups are represented primarily by Armstrong and Gara loams, and Lamoni clay loam, on the hillsides and uplands. These range from somewhat poorly to moderately well-drained. Nodaway silt loam and Zook silty clay loam make up the other dominant soil groups, both being alluvial floodplain soils ranging from moderately well drained to poorly drained (USDA 1990 and 2007).

2.4 Land Use and Land Cover

The land use and land cover of the Muddy Creek watershed is shown in Figure 2 and summarized by state in Table 1. The dominant land uses and land covers for the entire watershed are grassland (50.6 percent), cropland (24.2 percent) and forest and woodland (13.4 percent) with urban areas and land dominated by herbaceous vegetation occupying 4.6 and 3.5 percent of the watershed area, respectively.

Table 1. Land use/land cover in the Muddy Creek watershed (MoRAP 2005 and IGSDNR 2004).

Land Use/ Land Cover	Missouri			Iowa			Entire Watershed		
	Watershed Area			Watershed Area			Watershed Area		
	Acres	Square Miles	Percent	Acres	Square Miles	Percent	Acres	Square Miles	Percent
Urban	3264	5.1	4.7	318	0.5	3.8	3582	5.6	4.6
Cropland	15679	24.5	22.4	3277	5.1	39.5	18956	29.6	24.2
Grassland	35373	55.3	50.6	4244	6.6	51.1	39617	61.9	50.6
Forest/Woodland	10074	15.7	14.4	404	0.6	4.9	10478	16.3	13.4
Open Water	667	1.0	0.9	27	0.1	0.3	694	1.1	0.9
Barren	72	0.1	0.1	0	0	0	72	0.1	0.1
Herbaceous	2740	4.3	3.9	ND	ND	ND	2740	4.3	3.5
Wetland	2064	3.2	3.0	28	0.1	0.4	2092	3.3	2.7
Total	69933	109.2	100	8298	13.0	100	78231	122.2	100

Note: MoRAP = Missouri Resource Assessment Partnership
IGSDNR = Iowa Geological Survey, Department of Natural Resources
ND = No Data. Iowa's land cover data do not differentiate herbaceous cover from other land covers.

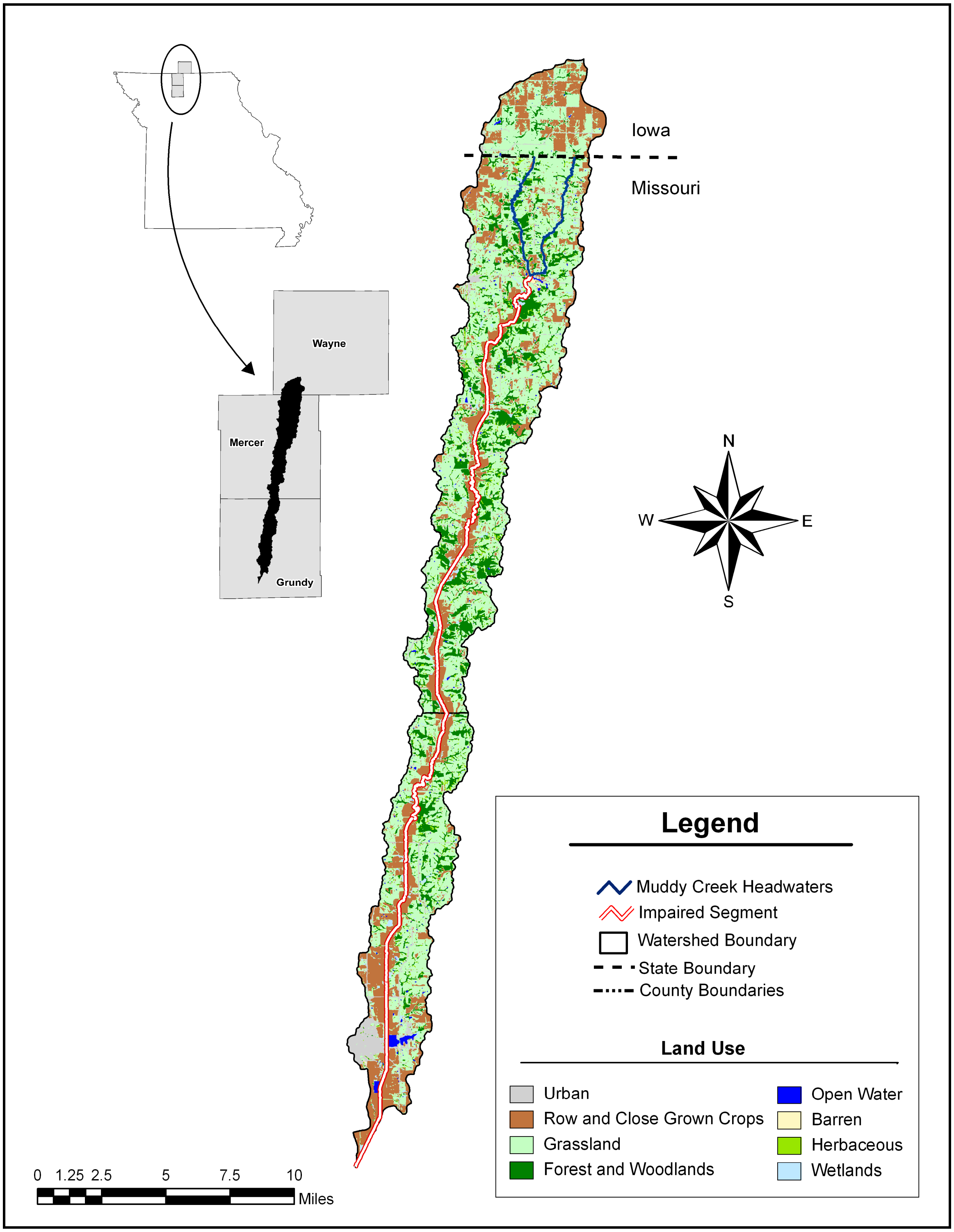

Figure 2. Land use/land cover in the Muddy Creek watershed (MoRAP 2005 and IGSDNR 2004)

2.5 Defining the Problem

A TMDL is needed for Muddy Creek because it has been determined to not be meeting general water quality criteria (see Section 4.2). As noted in Section 1, Muddy Creek was originally placed on the 2002 303(d) List based on observed impairments noted during a visual/benthic low-flow survey conducted in 2000. Visual stream surveys were conducted at three sites in Mercer County, identified in Figure 3, and the study concluded that, compared to other streams in the area, overall biological diversity in Muddy Creek appeared to be reduced. The report noted in particular that:

- Muddy Creek is heavily channelized, which may contribute to a loss of aquatic habitat.
- Rocks appeared to be darkened by manganese, possibly indicating periods of low dissolved oxygen.
- The water was slightly green and prostrate and filamentous algae were more prominent than in other nearby streams, possibly indicating increased nutrients.

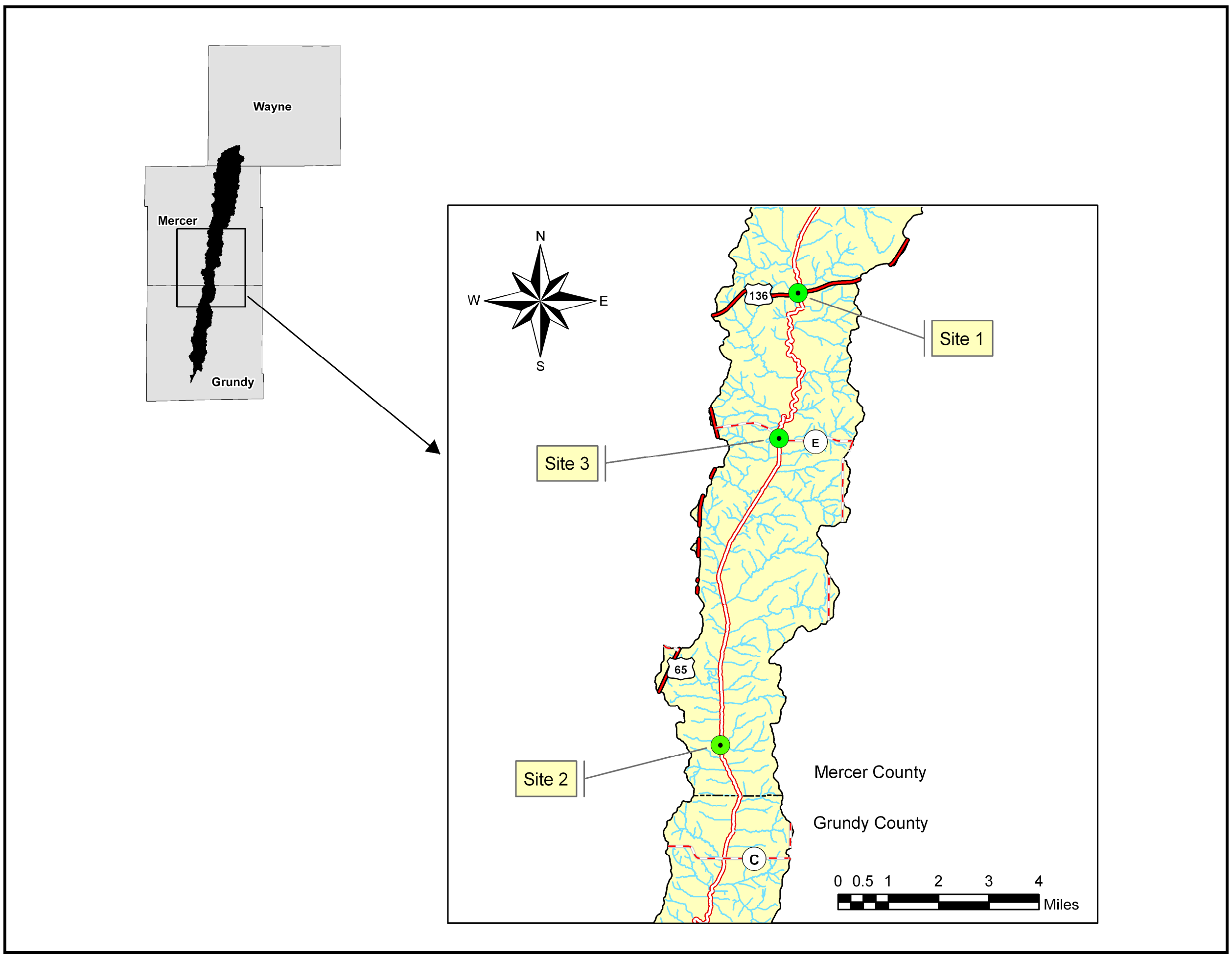

Figure 3. Location of sample sites from 2000 visual/benthic stream survey

Biological data from the Department's 2007 biological and habitat assessment study, summarized in Table 2, was used to assess impairment of the macroinvertebrate community in Muddy Creek (MDNR 2007). Macroinvertebrate stream condition index scores of 16 or greater are considered to reflect unimpaired macroinvertebrate communities. Eight of the nine samples (88.9 percent) in Muddy Creek scored 16 or higher, compared with 79.5 percent for all samples in the ecological drainage unit where Muddy Creek is located. By this standard, the macroinvertebrate community in Muddy Creek has been judged to be unimpaired.

Table 2. Aquatic macroinvertebrate stream condition index scores (MSCI)

Org	Site	Site Name	Date	MSCI Score
MDNR	1	Muddy Cr. @Sec.27-28,61N,24W	Fall 2006	18
MDNR	2	Muddy Cr. @Sec. 15-16,61N,24W	Fall 2006	18
MDNR	3	Muddy Cr. @SW Sec.14,62N,24W	Fall 2006	20
MDNR	4	Muddy Cr. @NW Sec.24,63N,24W	Fall 2006	20
MDNR	5	Muddy Cr. @NW Sec.24,64N,24W	Fall 2006	20
MDNR	2	Muddy Cr. @Sec. 15-16,61N,24W	Spring 2007	16
MDNR	3	Muddy Cr. @SW Sec.14,62N,24W	Spring 2007	14
MDNR	4	Muddy Cr. @NW Sec.24,63N,24W	Spring 2007	18
MDNR	5	Muddy Cr. @NW Sec.24,64N,24W	Spring 2007	18

Although the biological assessment and habitat study did not reveal an overall water quality impairment, and failed to indicate impairment of the macroinvertebrate community, some of the findings and conclusions within the report are worth noting:

- During fall sampling, both total nitrogen and total phosphorous concentrations at site 1 (downstream of the Trenton wastewater treatment plant) exceeded EPA's recommended criteria for streams in ecoregion IX (level III, ecoregion 40).
- During higher-flow spring sampling, total phosphorus exceeded EPA's recommended criteria for streams in ecoregion IX at 3 out of 4 sites sampled.
- Dissolved oxygen concentrations were consistent between seasons and sampling sites, and did not fall below the state water quality criterion of 5 mg/L.
- Three out of five of the Muddy Creek sampling sites scored below the acceptable 75 percent threshold when comparing habitat assessments in Muddy Creek to assessment from the bioreference streams.
- Assessments of riparian zone conditions range from mixed to very poor.
- Habitat assessment and stream dimension measurements revealed "significant physical alterations to the stream", including evidence of historic channelization throughout the study area, and concluded that the macroinvertebrate evaluation may not give the full assessment of the overall quality of the stream.

3 Source Inventory

This section summarizes the available information on potential known sources of pollutants in the Muddy Creek watershed. Point (or regulated) sources are presented first, followed by nonpoint (or unregulated) sources.

3.1 Point Sources

The term "point source" refers to any discernible, confined and discrete conveyance, such as a pipe, ditch, channel, tunnel or conduit, by which pollutants are transported to a water body. Point sources are regulated through the Missouri State Operating Permit program, and include municipal wastewater treatment facilities[3]. By law, point sources also include: concentrated animal feeding operations, or CAFOs (where animals are confined and maintained or fed); storm water discharges from municipal separate storm sewer systems; and storm water runoff from construction and industrial sites. All of the permitted facilities in the Missouri portion of the Muddy Creek watershed are listed in Table 3 and shown in Figure 4. The single permitted facility in the Iowa portion of the watershed is listed in Table 4 and also shown in Figure 4.

Table 3. Missouri permitted facilities in the Muddy Creek watershed

Facility ID	Facility Name	Receiving Stream	Design Flow (MGD)	Permit Expiration Date
MO-0039748	Trenton Municipal WWTF	Muddy Creek	1.9	12/29/2010
MO-0056057	Mercer WWTF	Unnamed Tributary Muddy Creek	0.048	12/04/2013
MO-G010035	Premium Standard Farms Wiles Farm	Muddy Creek	General Permit	02/23/2011
MO-G010495	Mike Henke B&G Facility	Unnamed Tributary Muddy Creek	General Permit	02/23/2011
MO-G490027	Norris Aggregate Products	Tributary Little Muddy Creek	General Permit	10/05/2011
MO-G490496	Trenton Transit Mix	Tributary Muddy Creek	General Permit	10/05/2011
MO-G490810	City of Trenton Street Department	Unnamed Tributary Muddy Creek	General Permit	10/05/2011
MO-R10C154	Brad Vogel Farm	Unnamed Tributary Little Muddy Creek	Storm Water Permit	02/07/2012
MO-R12A067	ConAgra Foods - Trenton	Unnamed Tributary Muddy Creek	Storm Water Permit	07/27/2011
MO-R109BC8	Trenton Municipal Airport	Muddy Creek	Storm Water Permit	03/07/2012
MO-R109BU5	Trenton Municipal Utilities WWTF	Muddy Creek	Storm Water Permit	03/07/2012

[3] The Missouri State Operating Permit program is Missouri's program for administering the federal National Pollutant Discharge Elimination System program.

Facility ID	Facility Name	Receiving Stream	Design Flow (MGD)	Permit Expiration Date
MO-R109T14	Trenton Supportive Housing	Unnamed Tributary Muddy Creek	Storm Water Permit	03/07/2012
MO-R240275	Hoffman & Reed, Inc. - Dry Plant North	Unnamed Tributary Muddy Creek	Storm Water Permit	02/19/02014
MO-R240302	Hoffman & Reed, Inc. - Liquid Plant South	Unnamed Tributary Muddy Creek	Storm Water Permit	02/19/02014
MO-R240415	Meinecke Crop Care – Tom's Agspray	Unnamed Tributary Little Muddy Creek	Storm Water Permit	02/19/02014
MO-R80F017	Trenton Municipal Airport	Muddy Creek	Storm Water Permit	10/04/2012

Table 4. Iowa permitted facilities in the Muddy Creek watershed

Permit number	Facility Name	Receiving Stream	Design Flow (MGD)	Permit Expiration Date
9352001	City of Lineville STP	Unnamed Tributary Little Muddy Creek	0.0344	06/11/2012

Although there are a number of permitted facilities within the Muddy Creek watershed in Missouri, there are only two site-specific permits with permitted design flows. The Trenton Wastewater Treatment Plant, located near the mouth of Muddy Creek, has the largest design flow, with an allowable discharge of 1.9 million gallons per day. The Trenton Wastewater Treatment Plant accounts for 98 percent of the total non-storm water design flows shown in Table 3. This facility merits some attention because it is the dominant point source discharger in the watershed, and also because the 2007 biological assessment report notes relatively high levels of nutrients and chloride downstream. However, because the original assessment of Muddy Creek as impaired took place well upstream of Trenton, the treatment facility is not considered the source of the aquatic life impairment on the 2008 303 (d) List.

The facility currently consists of an extended aeration treatment plant with aerobic digesters and pump station, along with a two-cell lagoon and peak flow retention basin. Peak flow from the lagoon is discharged from outfall #002 and is dependent upon actual storm water conditions. Peak flow from the retention basin is redirected through the main treatment plant. Sludge from the treatment plant is land applied.

Like all wastewater treatment plants in Missouri, the Trenton Wastewater Treatment Plant must meet the requirements of an operating permit issued by the Department. This permit contains discharge limits that the treatment plant must meet to be protective of instream water quality standards. The current discharge permit was most recently reissued December 30, 2005 and expires December 29, 2010. At the direction of EPA, when the operating permit for the Trenton Wastewater Treatment Plant is next renewed, a condition will be placed in the permit requiring the facility to eliminate Outfall #002 and redirect overflow from the lagoon into the mechanical treatment plant.

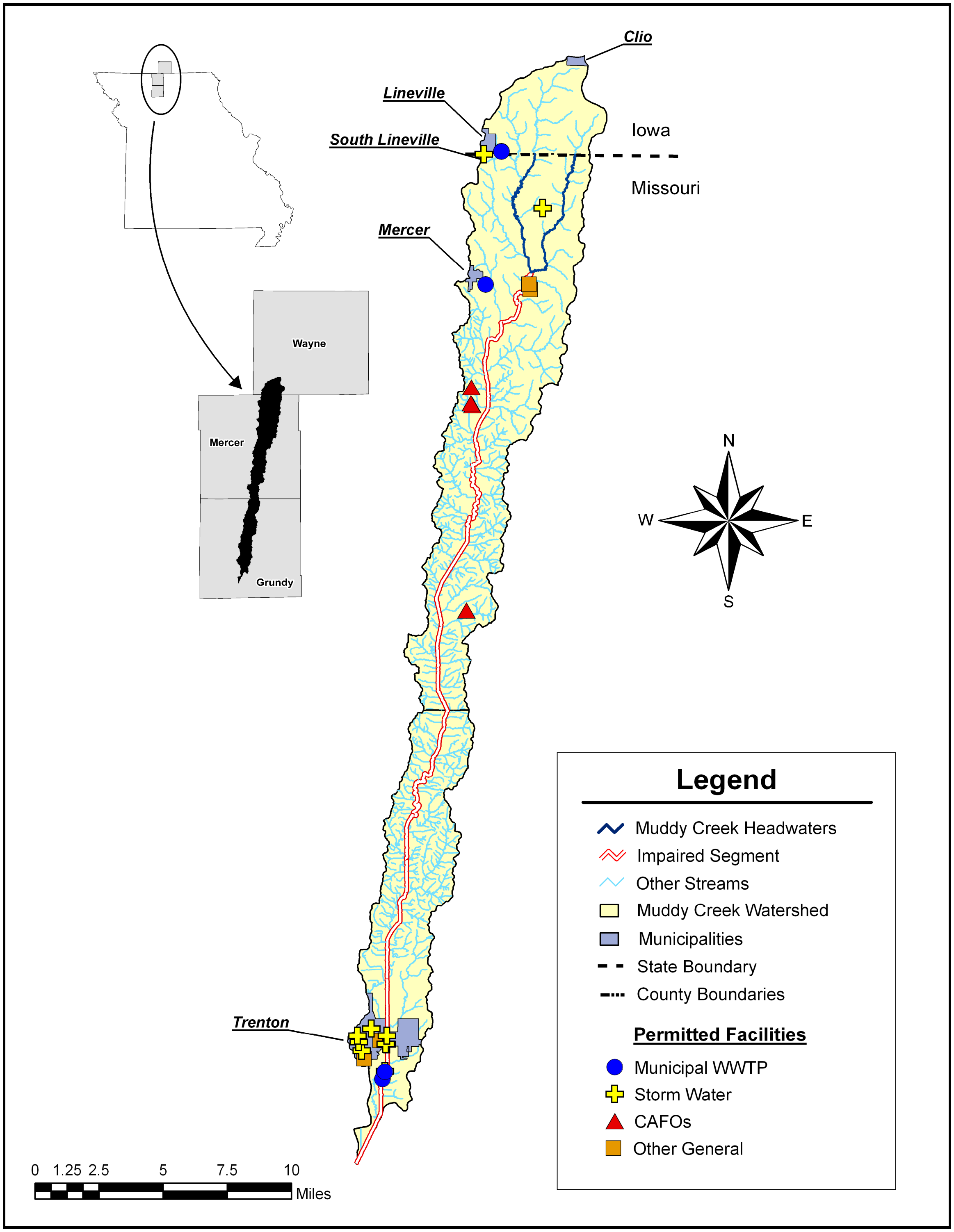

Figure 4. Locations of permitted facilities in the Muddy Creek watershed

The remaining non-storm water permitted discharger in the Muddy Creek watershed in Missouri is the Mercer Wastewater Treatment Plant, a four-cell lagoon system with a permitted design flow of 0.048 million gallons per day. Although this facility is upstream of the assessed impairment, its small size and location suggest that it is also unlikely to be a significant contributor to the assessed aquatic life impairment. The outfall discharges to an unclassified tributary to Muddy Creek approximately 7 to 17 miles upstream of the visual benthic survey sites.

In addition to site-specific permits, there are a number of facilities with general permits, including storm water permits, within the Muddy Creek watershed in Missouri. General permits are issued to activities that are similar enough to be covered by a single set of requirements. Storm water permits are issued to activities (e.g., land disturbance) that are similar enough to be covered by a single set of requirements and are expected to discharge in response to storm events. Both general and storm water permits are meant to be flexible enough to allow for ease and speed of issuance while providing the required protection of water quality. It should be noted that both municipalities located within the watershed in Missouri – Trenton and Mercer – each have populations under 10,000, and therefore are not required to obtain storm water permits issued for municipal separate storm sewer systems.

Livestock operations where animals are maintained or fed under confined conditions but which maintain fewer than 300 animal units are not legally defined as CAFOs under state regulations. Additionally, facilities that are defined as CAFOs but which maintain fewer than 1,000 animal units are not required to obtain a Missouri State Operating Permit. The National Agricultural Statistics Service also reports there are a number of hogs and pigs, and poultry layers and broilers in the counties containing the Muddy Creek watershed (USDA 2009). While there are no permitted poultry operations in and around the Missouri portion of the watershed, there are two permitted swine CAFOs within the watershed, each with storm water outfalls and each engaging in land application of animal waste.

Although it is possible that there are also unregulated animal feeding operations within the watershed, these operations are not regulated by the Department and there is no data available on their numbers or locations. Unregulated operations that do not properly manage animals or their waste may potentially be acting as point sources of nutrients and oxygen-consuming substances that could contribute to a water quality impairment in Muddy Creek.

The small portion of the Muddy Creek watershed that extends into Iowa contains only one site-specific permit administered through the National Pollutant Discharge Elimination System program. This facility is the city of Lineville's sewage treatment plant, which consists of a three-cell waste stabilization lagoon with a permitted average wet weather design flow of 0.0344 million gallons per day. The city of Clio does not have a central sewer system or a wastewater treatment facility. Like Missouri, there are no municipal separate storm sewer systems in the Iowa portion of the watershed.

Illicit straight pipe discharges of household waste are also potential point sources in rural areas. These are discharges straight into streams or land areas and are different than illicitly connected sewers. There is no specific information on the number of illicit straight pipe discharges of household waste in the Muddy Creek watershed.

3.2 Nonpoint Sources

Nonpoint sources include all other categories not classified as point sources. Potential nonpoint sources contributing to the impairment in the Muddy Creek watershed include runoff from agricultural areas, runoff from urban areas, onsite wastewater treatment systems, and various sources associated with riparian habitat conditions. Each of these is discussed further in the following sections.

3.2.1 Runoff from Agricultural Areas

The land use and land cover data indicate there are nearly 19,000 acres of cropland in the Muddy Creek watershed, which accounts for roughly 24 percent of the watershed area in both Iowa and Missouri (see Table 1) (MoRAP 2005 and IGSDNR 2004). Lands used for agricultural purposes can be sources of sediment, nutrients and oxygen-consuming substances in the creek. Accumulation of nitrogen and phosphorus on cropland occurs primarily from decomposition of residual crop material and fertilization with chemical and manure fertilizers. Nutrients and organic materials from crop fields are transported to adjacent streams during precipitation events through the processes of surface runoff and soil erosion. These processes can be compounded by tilling of farm fields and by applying fertilizers prior to precipitation events or at rates exceeding the assimilative capacity of the soil. As noted in Section 2.3, roughly 87 percent of the soils in the Muddy Creek watershed in Missouri have slow or very slow infiltration rates and much of the upland area is considered highly or potentially highly erodible.

Countywide data from the National Agricultural Statistics Service (USDA 2009) were combined with the land cover data for the Muddy Creek watershed to estimate there are approximately 9,183 cattle in the Missouri portion of the watershed[4]. A regional livestock specialist has confirmed that the majority of the cattle being raised in this area are in cow-calf grazing operations[5]. These cattle are therefore most likely located on the approximately 35,373 acres of grassland/pastureland in the Missouri side of the watershed and runoff from these areas can also be a potential source of nutrients and oxygen-consuming substances. For example, animals grazing in pasture areas deposit manure directly upon the land surface and, even though a pasture may be relatively large and animal densities low, the manure will often be concentrated near the feeding and watering areas in the field. These areas can quickly become barren of plant cover and increase the possibility of erosion and contaminated runoff during a storm event. When pasture land is not fenced off from the stream, cattle or other livestock may contribute nutrients directly to the stream while walking in or adjacent to the water body.

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[4] According to the National Agricultural Statistics Service, there are an estimated 70,526 head of cattle in Grundy and Mercer Counties (USDA, 2007). According to the 2005 Land Use Land Cover data from the Missouri Resource Assessment Partnership there are 424.7 square miles of grassland in Grundy and Mercer Counties (MoRAP, 2005). These two values result in a cattle density of approximately 166 cattle per square mile of grassland. This density was multiplied by the number of square miles of grassland in the Muddy Creek watershed to estimate the number of cattle in the watershed.
[5] Shawn Deering, Livestock Specialist, University of Missouri Extension Service, Northwest Region, personal communication, February 23, 2010.

Employing a similar analysis using agricultural and land use data from Iowa, it is estimated there are roughly 627 cattle in the Iowa portion of the Muddy Creek watershed. This results in an overall livestock density of 48 cattle per square mile in the watershed (IGSDNR 2004 and USDA 2009). It should be noted this estimated density is variable and may be dependent upon the locations of any animal feeding operations in Wayne County, Iowa.

3.2.2 Runoff from Urban Areas

Storm water runoff from urban areas can also be a significant source of nutrients and oxygen consuming substances. In fact, phosphorus loads from residential areas can be comparable to or higher than loading rates from agricultural areas (Reckhow *et al.* 1980; Athayde *et al.* 1983). In addition, storm water runoff from parking lots and buildings is warmer than runoff from grassy and woodland areas. This difference in surface runoff temperature can lead to higher instream water temperatures that lower the dissolved oxygen saturation capacity of the stream. Excessive discharge of suspended solids from urban areas can also lead to streambed siltation problems. Furthermore, leaking or illicitly connected sewers can also be a significant source of pollutant loads within urban areas.

Approximately 5.6 square miles (4.6 percent) of the Muddy Creek watershed is classified as urban, and 91 percent of the urban land use is within the Missouri portion of the watershed. Of this urban land use within Missouri, 91 percent is accounted for by the city of Trenton at the downstream end of the watershed. Fifty-eight percent of Trenton's incorporated area is within the watershed and Muddy Creek flows through this portion of the city. As noted earlier, Trenton does not have a storm water management plan in place, and is a likely contributor of urban nonpoint source runoff to Muddy Creek.

3.2.3 Onsite Wastewater Treatment Systems

Onsite wastewater treatment systems (e.g., septic systems) that are properly designed and maintained should not serve as a source of contamination to surface waters. However, onsite wastewater treatment systems do fail for a variety of reasons. When these systems fail hydraulically (surface breakouts) or hydrogeologically (inadequate soil filtration) there can be adverse effects to surface waters (Horsley and Witten 1996). Failing septic systems are sources of nutrients that can reach nearby streams through both surface runoff and groundwater flows.

The exact number of onsite wastewater systems in the Muddy Creek watershed is unknown. However, as discussed in Section 2.2, the estimated rural population in the Missouri portion of the Muddy Creek watershed is 1,050 persons[6] (U.S. Census Bureau 2001a). Based on this population, and an average density of 2.5 persons per household, there may be approximately 420 systems in the Missouri portion of the watershed.

Although there is no precise information available on the failure rate of onsite wastewater treatment systems within the Muddy Creek watershed, EPA reports that the statewide failure rate

[6] The total watershed population minus the population of all urban areas.

of onsite wastewater systems in Missouri is 30 to 50 percent (EPA 2002). Because they may potentially be a source of nutrients and oxygen-demanding substances, onsite wastewater treatment systems are considered a possible source of pollutants to Muddy Creek.

3.2.4 Riparian Corridor Conditions

Riparian corridor[7] conditions can also have a strong influence on nutrient and sediment loading to the stream, and on instream dissolved oxygen. Wooded riparian buffers are a vital functional component of stream ecosystems and are instrumental in the detention, removal, and assimilation of sediment and nutrients before they reach surface water. Therefore, a stream with a good riparian zone is generally better able to moderate the impacts of high sediment and nutrient loads than a stream with a poor riparian zone. Wooded riparian corridors can also help by providing shading that reduces stream temperatures and cooler stream temperatures can result in increased dissolved oxygen saturation capacity of the stream.

As indicated in Table 5, roughly 27 percent of the land in the riparian corridor adjacent to Muddy Creek is classified as grassland. Non-native grassland provides limited riparian habitat and very little shading compared to wooded areas and, as previously mentioned, can be subject to erosion and nutrient loading associated with livestock activity. Another 18 percent of the riparian area is classified as cropland which, like grassland, provides limited riparian habitat compared to wooded areas and leaves these areas more susceptible to soil erosion and high nutrient loads.

Forty-four percent of the riparian area is classified in the land cover as forest and wetland, roughly equivalent to the area classified as cropland and grassland. While these more naturally vegetated areas along the creek may serve to mitigate the effects of pollutants and conditions that may contribute to the aquatic life impairment, it should be noted that the riparian corridor in Muddy Creek comprises a very narrow zone within a floodplain overwhelmingly dominated by row crop agriculture.

Along with conditions of the riparian corridor, significant portions of the Muddy Creek stream channel itself have been straightened, or channelized. One of the primary effects of stream channelization is an increase in the velocity of water moving down stream. This increase in stream velocity can contribute to a reduction in base flows, which can be associated with increased water temperature and decreased levels of dissolved oxygen. Increased velocity can also lead to increased erosion of stream beds and stream banks which, in turn, can result in increased deposition of sediments downstream. Both erosion and sedimentation can have negative impacts on aquatic life.

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[7] A riparian corridor (or zone or area) is the linear strip of land running adjacent to a stream bank.

Table 5. Percentage of land cover within Muddy Creek riparian corridor, 30-meter (MoRAP 2005).

Land Use/Land Cover	Missouri
Urban	2.4
Cropland	17.6
Grassland	27.2
Forest & Woodland	2.5
Open Water	5.0
Barren	0
Herbaceous	3.8
Wetland	41.5
Total	100

Note: MoRAP = Missouri Resource Assessment Partnership

4 Applicable Water Quality Standards and Numeric Water Quality Targets

The purpose of developing a TMDL is to identify the pollutant loading that a water body can receive and still achieve water quality standards. Water quality standards are therefore central to the TMDL development process. Under the federal Clean Water Act, every state must adopt water quality standards to protect, maintain, and improve the quality of the nation's surface waters (U.S Code Title 33, Chapter 26, Subchapter III (U.S. Code 2009)). Water quality standards consist of three components: designated beneficial uses, water quality criteria to protect those uses, and an antidegradation policy.

4.1 Designated Beneficial Uses

The designated beneficial uses of Muddy Creek, WBID 0557, are:

- Livestock and Wildlife Watering
- Protection of Warm Water Aquatic Life
- Protection of Human Health (Fish Consumption)
- Whole Body Contact Recreation – Category B
- Secondary Contact Recreation

The use that is impaired is the Protection of Warm Water Aquatic Life. Although there is no impaired use identified for Muddy Creek on the 2008 303(d) List, Protection of Warm Water Aquatic Life is noted as the impaired use on the Department's 2004/2006 303(d) List. As such, Protection of Warm Water Aquatic Life is considered the impaired use for the purposes of this TMDL. The designated uses and stream classifications for Missouri may be found in the Water Quality Standards at 10 CSR 20-7.031(1)(C),-(1)(F) and Table H (Missouri Secretary of State 2008).

4.2 Water Quality Criteria

Because Muddy Creek is impaired by unknown pollutants, specific criteria cannot be cited. However, all Missouri streams are protected by the general criteria found in the Water Quality Standards at 10 CSR 20-7.031 (3). The particular criteria that could apply to this creek state:

(A) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.

(C) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.

(D) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life.

(G) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

4.3 Antidegradation Policy

Missouri's water quality standards include EPA's "three-tiered" approach to antidegradation, which may be found at 10 CSR 20-7.031(2) (Missouri Secretary of State 2008).

Tier 1 – Protects existing uses and a level of water quality necessary to maintain and protect those uses. Tier 1 provides the absolute floor of water quality for all waters of the United States. Existing instream water uses are those uses that were attained on or after November 28, 1975, the date of EPA's first Water Quality Standards Regulation.

Tier 2 – Protects and maintains the existing level of water quality where it is better than applicable water quality criteria. Before water quality in Tier 2 waters can be lowered, there must be an antidegradation review consisting of: (1) a finding that it is necessary to accommodate important economical and social development in the area where the waters are located; (2) full satisfaction of all intergovernmental coordination and public participation provisions; and (3) assurance that the highest statutory and regulatory requirements for point sources and best management practices for nonpoint sources are achieved. Furthermore, water quality may not be lowered to less than the level necessary to fully protect the "fishable/swimmable" uses and other existing or designated uses.

Tier 3 – Protects the quality of outstanding national and state resource waters, such as waters of national and state parks, wildlife refuges, and exceptional recreational or ecological significance. There may be no new or increased discharges to these waters and no new or increased discharges to tributaries of these waters that would result in lower water quality.

Waters in which a pollutant is at, near or exceeds the water quality criteria are considered in Tier 1 status for that pollutant. Therefore, the antidegradation goal for Muddy Creek is to restore the stream's water quality to a level that meets water quality standards.

5 TMDL Development

5.1 Water Quality Data

To help understand and characterize the nature of the unknown impairment in Muddy Creek, EPA Region 7 collected water quality data at five sample locations on August 24, 2009 (Appendix A.2) Together with historic water quality monitoring data collected by Premium Standard Farms and water chemistries collected as part of the Department's biological assessment (Appendix A.1), EPA's data were used in the development of load duration curves to model inputs of total nitrogen, total phosphorus and total suspended solids across a spectrum of flow conditions.

5.2 Water Quality Targets

As already noted, the cause of impairment to the aquatic community in Muddy Creek is unknown. The combination of natural geology, topography and land use in this former prairie region of the state is believed to have reduced the amount, and impaired the quality, of habitat for aquatic life. The major water quality problems in this area result from excessive nutrients and increased rates of sediment deposition due to erosion from stream banks and agricultural land, loss of stream length and stream channel heterogeneity due to channelization, and changes in basin hydrology that have increased flood flows and prolonged low flow conditions. Because TMDLs are not written to address habitat issues, the Muddy Creek TMDL must target water quality conditions that attain the protection of warm water aquatic life designated use. Load capacities must be developed to reduce those pollutants causing or contributing to the unknown impairment. Therefore, given the information derived from the Department's visual/benthic survey, which notes relatively high algal growth and possible low dissolved oxygen conditions, this Muddy Creek TMDL will address sediment and nutrients as TMDL targets. In a review of variables and their importance in dissolved oxygen modeling, Nijboer and Verdonschot (2004) categorized the impact of a number of variables on oxygen depletion. For this TMDL, the effects of temperature and the physical aspects of the stream itself were discounted. Pollutants which result in oxygen concentrations below saturation are:

- fine particle size of bottom sediment
- high nutrient levels (nitrogen and phosphorus)
- suspended particles of organic matter

Because these three variables vary to a large extent based on anthropogenic influences, they are appropriate targets for a TMDL written to address an impairment where the pollutant is unknown. Targeting these pollutants will ensure that already limited in-stream habitat is protected from additional sedimentation and that nutrients do not cause or contribute to excessive algal growth or a dissolved oxygen impairment.

5.3 TMDL Modeling[8]

There are many quantitative indicators of sediment, such as total suspended solids, turbidity and bed load sediment, which are appropriate to describe sediment in rivers and streams. Total suspended solids was selected as the numeric target for sediment in the TMDL because it enables the use of the available data. To address nutrients, both total nitrogen and total phosphorous are selected because both nutrients are generally elevated by point and nonpoint sources.

5.3.1 Total Suspended Solids

Since fine particle sized sediment and suspended particles of organic matter are derived from similar loading conditions of terrestrial and stream bank erosion, this TMDL will have total suspended solids (sediment) as one of its allocations. See Appendix C for a discussion of the development of total suspended solids targets. This target was derived based on a reference approach by targeting the 25th percentile base load concentration (5.75 mg/L) of total suspended solids measurements collected by the U.S. Geological Survey, or USGS, in the geographic region where Muddy Creek is located (see Appendix B for a list of sites and data)[9].

To develop the TMDL expression of maximum daily loads, the background discharge at the stream outlet was modified from the traditional approach using synthetic flow estimation. Since the design flows from permitted facilities would overwhelm the natural background low flow, the sum of permitted facility design flows was added to the derived stream discharge at all percentiles of flow to take into account the increase in flow volume as well as pollutant load.

5.3.2 Nutrients

To address nutrient levels of total nitrogen and phosphorous, the EPA nutrient ecoregion reference concentrations were used. For the ecoregion where Muddy Creek is located, the reference concentration for total nitrogen[10] is 0.855 mg/L and the reference concentration for total phosphorus is 0.092 mg/L (EPA 2001a and EPA 2001b).

To develop load duration curves for total nitrogen and total phosphorus, a method similar to that used for total suspended solids was employed. First, total nitrogen and total phosphorus measurements were collected from USGS sites in the vicinity of the impaired stream segment (Appendix B). These data were adjusted such that the median of the measured data was equal to the ecoregion reference concentration. This was accomplished by subtracting the difference of the data median and the reference concentration. Where this would result in a negative concentration, the data point in question was replaced with the minimum concentration seen in the measured data. This resulted in a modeled data set which retained much of the original variability seen in the measured data. This modeled data was then regressed as instantaneous load versus flow. The resultant regression equation was used to develop the load duration curve.

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[8] EPA Region 7 performed the modeling for this TMDL
[9] The EPA ecoregion for Muddy Creek is Level III 40, the Central Irregular Plains
[10] Total Kjeldahl nitrogen and nitrate plus nitrite as nitrogen

To develop the TMDL expression of maximum daily loads, the background discharge at the stream outlet was modified from the traditional approach using synthetic flow estimation. Since the design flows from permitted facilities would overwhelm the natural background low flow, the sum of permitted facility design flows was added to the derived stream discharge at all percentiles of flow to take into account the increase in flow volume as well as pollutant load.

6 Calculation of Load Capacity

Load capacity, or LC, is defined as the greatest amount of loading of a pollutant that a water body can receive without violating water quality standards. This load is then divided among the sum of the point source (wasteload allocation, or WLA) and nonpoint source (load allocation, or LA) contributions to the stream with an allowance for an explicit margin of safety, or MOS. If the margin of safety is implicit, no numeric allowance is necessary. The load capacity of the stream can therefore be expressed in the following manner:

$$LC = \sum WLA + \sum LA + MOS$$

The wasteload allocation and load allocation are calculated by multiplying the appropriate stream flow in cubic feet per second, or cfs, by the appropriate pollutant concentration in mg/L. A conversion factor of 5.395 is used to convert the units (cfs and mg/L) to pounds per day (lbs/day).

(stream flow in cfs)(maximum allowable pollutant concentration in mg/L)(5.395)= pounds/day

Critical flow conditions must be considered when the load capacity is calculated. Without a known pollutant, however, the critical period is difficult to determine. In this TMDL, load duration curves have been created. These models cover all flow conditions, so a target and load can be determined for different pollutants for any and all flows.

7 Wasteload Allocation (Point Source Load)

The wasteload allocation is the portion of the load capacity that is allocated to existing or future point sources of pollution. The sum of all non-storm water design flows from site-specific permitted dischargers in the Missouri portion of the Muddy Creek watershed is 1.948 million gallons per day (see Table 3). Wasteload allocations was calculated by using nutrient ecoregion reference concentrations and 25th percentile total suspended solids concentrations, and the sum of the design flows of all permitted facilities in the watershed.

The load duration curves for the targeted pollutants for Muddy Creek are depicted in Figures 5, 6 and 7. The "TMDL" curve represents the total load capacity of all point and nonpoint sources of pollutants, the "Sum of WLA" represents allocations for all point sources of pollutants with both static and storm water-based design flows, and the "Non-Storm Water" curve represents allocations attributed to sources of discharge with static design flows. The only storm water-based design flow incorporated into the modeling is from the storm water lagoon (outfall #2) at the Trenton Wastewater Treatment Plant. As noted in Section 3.1, this outfall will be eliminated at the next permit renewal and overflow from the lagoon redirected through the treatment plant.

Muddy Creek TMDL load capacities and wasteload allocations for nutrients and total suspended solids are outlined in Tables 6 through 11 for a range of flow conditions. Wasteload allocations are presented as a sum for the two site-specific point source dischargers in the Missouri portion of the watershed. This TMDL does not include wasteload allocations for point sources in Iowa. Since wasteload allocations are set only for Missouri, the wasteload allocations in Tables 7, 9 and 11 are the same as those for the entire watershed. Because of the size, location or permit conditions associated with each facility, neither are considered to be causing or contributing to conditions that may affect the assessed impairment of Muddy Creek, and none has been identified as a potential source of the impairment on the 2008 303(d) List. Consequently, wasteload allocations are not apportioned by facility.

Because the cause and the source of the impairment are unknown, a QUAL2K model was not developed for Muddy Creek. Consequently, no wasteload allocations have been developed for biochemical oxygen demand, and current permit effluent limits for this parameter will remain in effect for both the Trenton and Mercer treatment facilities. In addition, neither of these facilities currently has effluent limits for total nitrogen or total phosphorus, and since they are not considered to be causing or contributing to the impairment, no new wasteload allocation-based effluent limits will be developed. Similarly, although the facilities do currently have effluent limits for total suspended solids, no revised limits will be developed since the impairment is unknown and the facilities are not considered to be causing or contributing to an impairment.

Note that the margin of safety for these TMDLs is implicit and was not included in the allocations tables. Further discussion of the margin of safety can be found in Section 9.

8 Load Allocation (Nonpoint Source Load)

The load allocation includes all existing and future nonpoint sources and natural background contributions (40 CFR § 130.2(g)). The load allocations for the Muddy Creek TMDL are for all nonpoint sources of total phosphorus, total nitrogen and total suspended solids. These can include loads from agricultural lands, including cultivated cropland and grassland utilized for livestock grazing, runoff from urban areas, animal feeding operations and failing onsite wastewater treatment systems. TMDL load allocations for the entire Muddy Creek watershed are provided in Tables 6, 8 and 10, and were calculated based on the loads expressed in the load duration curves found in Figures 5, 6 and 7. The load allocations are intended to allow the nutrient and total suspended solids targets to be met at all locations within the stream under a variety of flow conditions.

Because the Missouri portion of the Muddy Creek watershed accounts for 89.4 percent of the total watershed area, Muddy Creek stream flow, TMDL values and nonpoint source load allocations were reduced proportionally from the allocations for the entire watershed. TMDL load allocations for the Missouri portion of the Muddy Creek watershed can be found in Tables 7, 9 and 11.

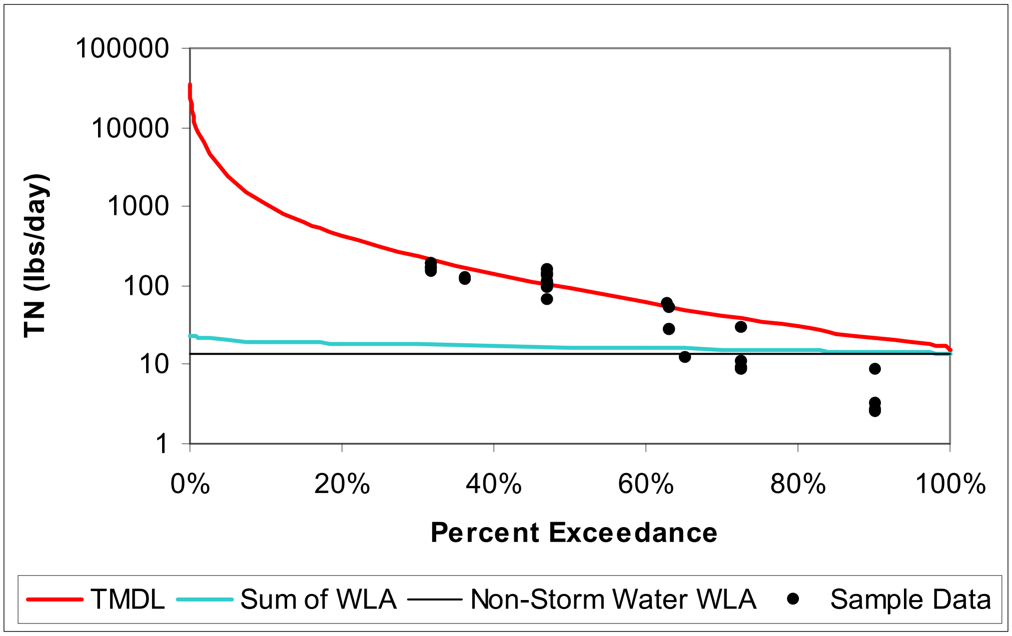

Figure 5. Muddy Creek load duration curve – total nitrogen.

Table 6. Muddy Creek total nitrogen allocations – entire watershed (lbs/day)

Percentile flow exceedance	Flow (cfs)	TMDL (LC)	Sum of WLA	LA
95%	4.2	19.38	14.18	5.20
90%	4.7	21.59	14.45	7.14
70%	9.1	42.11	15.55	26.56
50%	20.4	94.26	16.65	77.61
30%	48.3	234.01	17.94	216.07
10%	187.0	1054.01	19.94	1034.07
5%	389.0	2380.37	20.82	2359.55

Table 7. Muddy Creek total nitrogen allocations – Missouri only (lbs/day)

Percentile flow exceedance	Flow (cfs)	TMDL (LC)	Sum of WLA	LA
95%	3.8	18.83	14.18	4.65
90%	4.2	20.83	14.45	6.38
70%	8.2	39.29	15.55	23.74
50%	18.3	86.03	16.65	69.39
30%	43.2	211.11	17.94	193.17
10%	167.2	944.39	19.94	924.46
5%	347.8	2130.26	20.82	2109.44

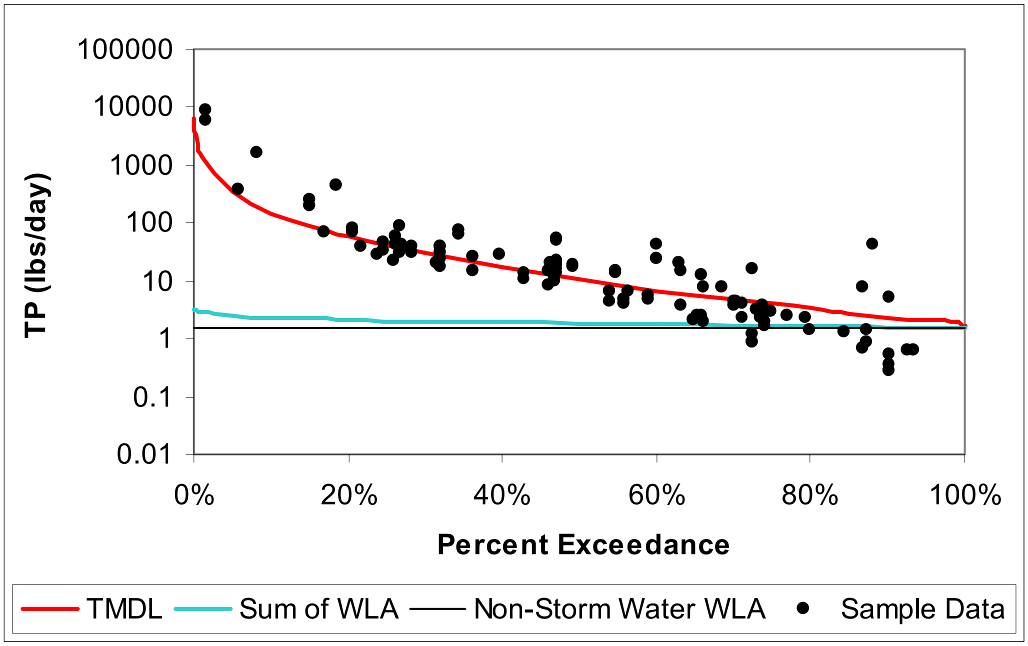

Figure 6. Muddy Creek load duration curve – total phosphorus.

Table 8. Muddy Creek total phosphorus allocations – entire watershed (lbs/day)

Percentile flow exceedance	Flow (cfs)	TMDL (LC)	Sum of WLA	LA
95%	4.2	2.09	1.53	0.56
90%	4.7	2.32	1.56	0.77
70%	9.1	4.53	1.67	2.86
50%	20.4	10.71	1.81	8.90
30%	48.3	29.61	2.01	27.60
10%	187.0	146.64	2.34	144.30
5%	389.0	348.61	2.51	346.10

Table 9. Muddy Creek total phosphorus allocations – Missouri only (lbs/day)

Percentile flow exceedance	Flow (cfs)	TMDL (LC)	Sum of WLA	LA
95%	3.8	2.03	1.53	0.50
90%	4.2	2.24	1.56	0.69
70%	8.2	4.23	1.67	2.55
50%	18.3	9.77	1.81	7.96
30%	43.2	26.69	2.01	24.68
10%	167.2	131.34	2.34	129.01
5%	347.8	311.93	2.51	309.42

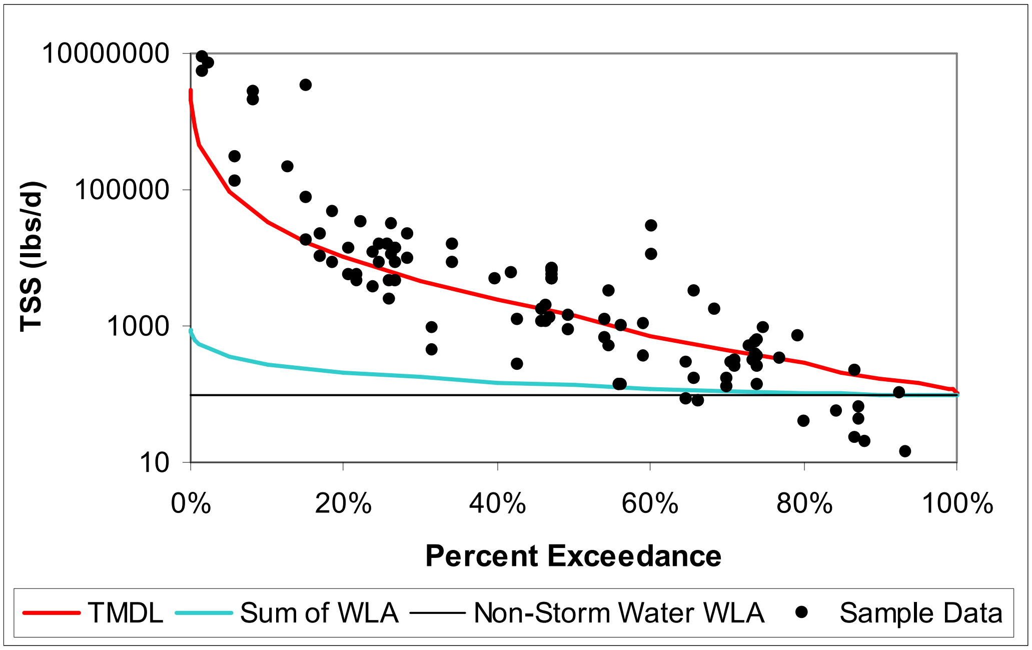

Figure 7. Muddy Creek load duration curve – total suspended solids.

Table 10. Muddy Creek total suspended solids allocations – entire watershed (lbs/day)

Percentile flow exceedance	Flow (cfs)	TMDL (LC)	Sum of WLA	LA
95%	4.2	142.68	95.52	47.16
90%	4.7	166.47	97.73	68.74
70%	9.1	432.09	110.40	321.69
50%	20.4	1365.05	133.24	1231.81
30%	48.3	4661.87	173.89	4487.98
10%	187.0	32186.55	277.85	31908.70
5%	389.0	91599.73	359.68	91240.05

Table 11. Muddy Creek total suspended solids allocations – Missouri only (lbs/day)

Percentile flow exceedance	Flow (cfs)	TMDL (LC)	Sum of WLA	LA
95%	3.8	137.68	95.52	42.16
90%	4.2	159.18	97.73	61.45
70%	8.2	397.99	110.40	287.60
50%	18.3	1234.48	133.24	1101.23
30%	43.2	4186.14	173.89	4012.26
10%	167.2	28804.23	277.85	28526.38
5%	347.8	81928.28	359.68	81568.60

9 Margin of Safety

A margin of safety is required in the TMDL calculation to account for uncertainties in scientific and technical understanding of water quality in natural systems. The margin of safety is intended to account for such uncertainties in a conservative manner. Based on EPA guidance, the margin of safety can be achieved through one of two approaches:

(1) Explicit - Reserve a portion of the load capacity as a separate term in the TMDL.
(2) Implicit - Incorporate the margin of safety as part of the critical conditions for the wasteload allocation and the load allocation calculations by making conservative assumptions in the analysis.

An implicit margin of safety was incorporated into the TMDL based on conservative assumptions applied to the development of the TMDL load duration curves. Among the conservative approaches used was to calculate wasteload allocations by targeting the 25^{th} percentile of total suspended solids concentrations in the geographic region in which Muddy Creek is located.

10 Seasonal Variation

Federal regulations at 40 CFR §130.7(c)(1) require that TMDLs take into consideration seasonal variation in applicable standards. The Muddy Creek TMDL takes seasonal variation into account through the use of load duration curves. Load duration curves represent the allowable pollutant load under different flow conditions and across all seasons. The results obtained using the load duration curve method are more robust and reliable over all flows and seasons when compared with those obtained under critical low-flow conditions.

11 Monitoring Plans

The Department has not yet scheduled post-TMDL monitoring for Muddy Creek. Depending upon the availability of resources, the Department may schedule and conduct such monitoring approximately three years after the TMDL is approved, or in a reasonable period of time following implementation of nonpoint source best management practices (see Section 12.2). The Department will, in any case, routinely examine physical habitat, water quality, the invertebrate community, and fish community data collected by other local, state and federal entities in order to assess the effectiveness of TMDL implementation. One example of such data is that generated by the Resource Assessment and Monitoring Program administered by the Missouri Department of Conservation. This program randomly samples streams across Missouri on a five to six year rotating schedule.

Another example of data that may be of use to assess the effectiveness of TMDL implementation is data collected by Stream Teams as part of the volunteer water quality monitoring program.

Although data is not currently being collected on Muddy Creek as part of this program, monitoring is taking place on other nearby streams in Mercer and Grundy counties. Given this proximity of individuals trained in water quality data collection, it may be possible to establish a similar monitoring program using these same volunteers on Muddy Creek. In addition, the Department can work with the local soil and water conservation districts to encourage members of their staff or the interested public – including landowners participating in the AgNPS SALT[11] project – to obtain volunteer water quality monitoring training that is offered by the Department. Information about this training could be disseminated through newsletters and brochures that are distributed as part of this project, as well as through general newsletters distributed by the soil and water conservation districts.

12 Implementation Plans

This section addresses both point and nonpoint source TMDL implementation plans.

12.1 Point Sources

As outlined in Section 7, since permitted point sources in the watershed are not thought to be causing or contributing to the aquatic life impairment in Muddy Creek, wasteload allocations are not being apportioned to each facility. As a result, no point source implementation plans are identified for the Muddy Creek TMDL, and no portion of this TMDL will be implemented through permit action at this time.

It is the intention of the Department that prior to considering implementation of any new wasteload allocations, nonpoint source pollutant controls will be developed and put into effect in the watershed, as outlined in Section 12.2. It is recommended that additional sampling be conducted in Muddy Creek in a reasonable period of time following implementation of nonpoint source controls, and prior to implementation of any wasteload allocations, in order to assess the water body's attainment of designated beneficial uses.

All permitted facilities within the Missouri portion of the impaired watershed will be inspected prior to next permit renewal to determine if additional best management practices or revised permit conditions are needed to ensure the facilities are not contributing nutrients, sediment or oxygen demanding pollutants to Muddy Creek. The inspections will include an assessment of the condition of the facilities and whether upgrades or additional measures are necessary.

While there is one permitted point source on the Iowa side of the Muddy Creek watershed, the city of Lineville's Wastewater Treatment Plant, the state of Missouri has no authority to regulate this facility. However, the Department will notify the Iowa Department of Natural Resources upon completion of this TMDL, and remains committed to working with the state of Iowa to ensure that Muddy Creek continues to meet water quality criteria at the state line.

[11] See Section 12.2 below for more information

12.2 Nonpoint Sources

While wasteload allocations for permitted point sources of pollutants are often the major component of a TMDL, nonpoint source load allocations for this TMDL account for a significant portion of the total load capacity. The implementation of this TMDL will initially be directed exclusively at pollutant reduction through control of nonpoint sources.

The Mercer County Soil and Water Conservation District is in the process of administering a seven year Agricultural Nonpoint Source Special Area Land Treatment, or AgNPS SALT[12], grant that was received in 2005. Best management practices, or BMPs, being implemented as part of this project are intended to address and improve agricultural land use practices that may be contributing to water quality problems associated with nonpoint source pollution in the Muddy Creek watershed. The concept of BMPs is one of a voluntary and site-specific approach to water quality problems. Activities or practices being implemented include various forms of pasture and cropland management, erosion control, groundwater protection, waste management, and riparian and stream bank protection. In addition, educating and providing information to landowners, including distributing newsletters and brochures, and conducting workshops and field tours, is an important component of this AgNPS SALT project.

The primary mechanism for measuring the success of this project is through the completion of semi-annual progress reports that evaluate the proportion of project goals completed, based on the importance assigned to each category. Measurements of water quality improvement in Muddy Creek rely on monitoring to be conducted by the Department, as well as biological monitoring to be conducted by local Stream Team volunteers throughout the life of the project. Although the water quality monitoring piece of this AgNPS SALT project has not yet been implemented as planned, Section 11 of this TMDL outlines a similar set of goals for post-TMDL monitoring.

13 Reasonable Assurances

The Department has the authority to issue and enforce Missouri State Operating Permits. For TMDLs that address point sources of pollution, effluent limits determined from TMDL wasteload allocations incorporated into a state permit, along with effluent monitoring reported to the Department, should provide a reasonable assurance that instream water quality standards will be met. In the case of Muddy Creek, however, permitted point sources have not been identified as contributing to the impairment.

In most cases, "Reasonable Assurance" in reference to TMDLs is intended to address only point sources. Any assurances that nonpoint sources of pollutants potentially contributing to an impaired aquatic community will implement measures to reduce their contribution in the future

[12] This program is funded through Missouri's one-tenth-of-one-percent parks, soils and water sales tax and is administered by the Department's Soil and Water Conservation Program. It allows county soil and water conservation districts to provide technical and financial assistance to landowners in addressing agricultural nonpoint source pollution problems on their land.

will not be found in this section. Instead, discussion of reduction efforts relating to nonpoint sources can be found in the "Implementation" section of this TMDL.

14 Public Participation

This water quality-limited segment of Muddy Creek is included on Missouri's 2008 303(d) List of impaired waters. EPA regulations require that TMDLs be subject to public review (40 CFR 130.7). Before finalizing the Muddy Creek TMDL the public has been notified of a 45 day comment period. Public notices to comment on the draft Muddy Creek TMDL have been distributed via mail and e-mail to major stakeholders in the watershed or other potentially impacted parties. Groups that received the public notice announcement include the Missouri Clean Water Commission, the Department's Water Quality Coordinating Committee, the Missouri Department of Conservation's Policy Coordinating Unit, Stream Team volunteers in the area, the Mercer County and Grundy County Soil and Water Conservation Districts, the Mercer County and Grundy County Commissions, and the state legislators representing Mercer and Grundy counties. In addition, since the headwaters of Muddy Creek originate in Iowa and flow into Missouri, a public notice announcement has been sent to the Iowa Department of Natural Resources' Water Quality Bureau. Announcement of the public notice period for this TMDL was also issued as a press release to local media outlets in the proximity of the Muddy Creek watershed. Finally, the public notice, the TMDL Information Sheet, and this document have been posted on the Department website, making them available to anyone with Internet access. Any comments received, and the Department's response to those comments, have been placed in the Muddy Creek administrative record, as noted below.

15 Administrative Record and Supporting Documentation

An administrative record on the Muddy Creek TMDL has been assembled and is being kept on file with the Department. It includes the following:

- Biological Assessment and Habitat Study Report, Muddy Creek, Grundy and Mercer Counties, September 2006 – March 2007, Missouri Department of Natural Resources, Environmental Services Program
- Stream Team survey data from Mercer and Grundy counties
- Load duration curve modeling data files
- Muddy Creek TMDL Information Sheet
- Public notice announcement
- Public comments and comment responses

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Appendix A
Water Quality Data
Appendix A.1 – Muddy Creek Historic Data
Collected by Premium Standard Farms and Missouri Department of Natural Resources, 2004 - 2009

Site	Org.	Year	Month	Day	Flow	Temp	DO	pH	SC	KJN	NH3N	NO3N	TN	TP	TSS	TRB	CBOD
					cfs	deg C	mg/L		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L
Highway M	PSF	2004	4	27	2.1	8	12.7	7.7			0.0499	0.3		0.2	1.99		
Independence St.	PSF	2004	4	27	1.5	10.3	9.5	8			0.0499	0.099		0.05	1.99		
Highway M	PSF	2004	5	25	300.5	17	8.4	7.9			0.1	5.2		1.1	1014		
Independence St.	PSF	2004	5	25	973.9	21.1	5.4	7.5			0.0499	2.3		1.76	1680		
Highway M	PSF	2004	6	22	3.6	17	8.2	8.1			0.0499	0.9		0.12	30		
Independence St.	PSF	2004	6	22	60.1	16	6.9	7.4			0.0499	0.8		0.15	47		
Independence St.	PSF	2004	7	27	0.7	19	7.9	8.1			0.0499	0.4		0.11	17		
Highway M	PSF	2004	7	28	1.01	18.7	7.9	8.1			0.0499	0.6		0.11	34		
Highway M	PSF	2004	8	24	8.4	18	7.7	8			0.34	0.2		0.78	540		
Independence St.	PSF	2004	8	24	10.01	20.4	5.8	7.3			0.0499	0.099		0.44	199		
Highway M	PSF	2004	9	21	0.6	19	6.2	7.8			0.0499	0.099		0.22	48		
Independence St.	PSF	2004	9	22	4.2	16.3	6.7	8			0.0499	0.099		0.13	9		
Highway M	PSF	2004	10	27	0.8	13	9.3	7.9			0.0499	0.099		0.21	7		
Independence St.	PSF	2004	10	27	50.1	14	11.3	8			0.0499	0.099		0.19	45		
Highway M	PSF	2004	11	22	1.6	7	9.2	7.8			0.0499	0.099		0.05	1.99		
Independence St.	PSF	2004	11	23	4.2	6	9.7	8			0.0499	0.099		0.05	7		
Highway M	PSF	2005	1	27	6.7	3		7.6			0.18	1.4		0.32	28		
Independence St.	PSF	2005	1	27	30.1	2		7.3			0.21	0.9		0.4	119		
Highway M	PSF	2005	2	21	20.01	3		7.6			0.0499	1.2		0.11	36		
Independence St.	PSF	2005	2	21	37.6	2		7.7			0.0499	0.7		0.15	84		
Highway M	PSF	2005	3	21	3.3	5		7.8			0.0499	0.099		0.07	1.99		
Independence St.	PSF	2005	3	21	18.8	6		7.8			0.0499	0.099		0.06	1.99		
Highway M	PSF	2005	4	26	8.4	8	9.5	7.9			0.0499	0.8		0.1	25		
Independence St.	PSF	2005	4	26	12.5	8	9.8	8.2			0.0499	1		0.14	48		
Highway M	PSF	2005	5	24	1.9	18	9.2	8.2			0.0499	0.6		0.14	36		
Independence St.	PSF	2005	5	24	6.3	16	10.2	8.1			0.0499	0.8		0.2	105		
Highway M	PSF	2005	6	21	1.9	20	7.3	7.7			0.17	0.3		0.1	9		
Independence St.	PSF	2005	6	21	7.5	20	7.9	8			0.0499	0.099		0.08	1.99		

Site	Org.	Year	Month	Day	Flow	Temp	DO	pH	SC	KJN	NH3N	NO3N	TN	TP	TSS	TRB	CBOD
					cfs	deg C	mg/L		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L
Highway M	PSF	2005	7	26	0.2	26	6.1	7.6			0.0499	0.2		0.13	21		
Independence St.	PSF	2005	7	26	1.9	26	8	7.6			0.0499	0.099		0.11	14		
Independence St.	PSF	2005	8	23	0.2	21	5.1	7.9			0.0499	0.099		0.09	4		
Independence St.	PSF	2005	9	26	2.01	21	3.7	7.9			0.0499	0.099		0.09	1.99		
Highway M	PSF	2005	10	24	0.1	12	7.2	8.1			0.0499	0.099		0.71	1.99		
Independence St.	PSF	2005	10	24	0.9	7	6.9	8.2			0.0499	0.099		0.06	20		
Highway M	PSF	2005	11	21	0.4	4	6.2	7.9			0.0499	0.099		4.31	1.99		
Independence St.	PSF	2005	11	21	0.7	3	4.6	7.4			0.0499	0.099		0.02499	9		
Highway M	PSF	2006	3	28	0.2	8		7.8			0.0499	0.099		0.11	13		
Independence St.	PSF	2006	3	28	1.9	7		7.3			0.0499	0.099		0.06	5		
Highway M	PSF	2006	4	26	0.4	9	7.2	7.6			0.0499	0.099		0.08	11		
Highway M	PSF	2006	5	24	1.9	20	4.8	7.9			0.0499	0.3		0.11	23		
Independence St.	PSF	2006	5	24	2	16	10.6	8.1			0.0499	0.2		0.07	9		
Highway M	PSF	2006	6	26	0.2	21	7.9	7.7			0.0499	0.2		0.06	16		
Independence St.	PSF	2006	6	26	0.7	19	9.3	7.9			0.0499	1.4		0.09	9		
Independence St.	PSF	2006	7	25	1.1	24	5.1	7.2			0.0499	0.099		0.08	14		
Independence St.	PSF	2006	8	22	0.6	22	6.8	7.1			0.0499	0.099		0.1	14		
28th St. Trenton Airport	MDNR	2006	9	19	1.4	18	8.5	8	452		0.01499	0.01	0.29	0.06		2.16	
Highway B	MDNR	2006	9	20	0.73	18	9.6	8.1	478		0.01499	0.00499	0.29	0.03		2.03	
Imperial St.	MDNR	2006	9	20	0.35	18	11.4	8.1	505		0.01499	0.00499	0.36	0.03		5.04	
Below Trenton WWTP	MDNR	2006	9	20	1.82	13.5	7.6	7.8	1040		0.01499	0.01	0.98	0.56		3.9	
Near Highway O	MDNR	2006	9	20	0.7	15	10	8	446		0.01499	0.00499	0.31	0.04		3.74	
Independence St.	PSF	2006	10	23	2.2	4	7.1	7.5			0.0499	0.099		0.11	34		
Highway M	PSF	2006	11	20	0.3	1	6.7	7.5			0.0499	0.099		0.13	4		
Independence St.	PSF	2006	11	20	1.1	1	9.1	7.3			0.0499	0.099		0.08	6		
Highway M	PSF	2006	12	22	16.7	5		7.9			0.0499	2.7		0.36	44		
Independence St.	PSF	2006	12	22	25.7	6		7.9			0.18	1.4		0.32	81		
Highway M	PSF	2007	1	26	3	1		7.4			0.2	0.8		0.32	79		
Independence St.	PSF	2007	1	26	3.3	1		7.7			0.0499	0.3		0.06	4		
Highway M	PSF	2007	2	21	75.1	0.6		7.9			0.47	1.6		0.93	97		
Independence St.	PSF	2007	2	21	40.1	0.4		7.9			0.95	1.3		0.88	17		
Highway M	PSF	2007	3	26	15.7	17		8.4			0.0499	0.6		0.1	16		

Site	Org.	Year	Month	Day	Flow	Temp	DO	pH	SC	KJN	NH3N	NO3N	TN	TP	TSS	TRB	CBOD
					cfs	deg C	mg/L		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L
Independence St.	PSF	2007	3	26	33.4	15		8.7			0.0499	0.6		0.29	47		
Highway B	MDNR	2007	3	27	27.4	20	7.2	7.9	426		0.01499	0.26	0.76	0.11		20.6	
28th St. Trenton Airport	MDNR	2007	3	27	36.1	19	7.1	7.9	405		0.01499	0.29	0.86	0.17		61.7	
Imperial St.	MDNR	2007	3	28	17.4	15	8	8	457		0.01499	0.17	0.65	0.08		13.4	
Near Highway O	MDNR	2007	3	28	27.9	16	8.4	7.8	436		0.01499	0.21	0.7	0.14		41.7	
Highway M	PSF	2007	4	23	5	14	8.1	7.7			0.0499	0.099		0.09	12		
Independence St.	PSF	2007	4	23	16.7	13	8.3	8			0.0499	0.099		0.1			
Highway M	PSF	2007	5	24	2.2	18.9	6.8	7.7			0.0499	0.099		0.13	10		
Independence St.	PSF	2007	5	24	25.01	19.1	7.4	7.9			0.0499	0.099		0.07	15		
Highway M	PSF	2007	6	27	0.8	26	7.8	7.8			0.0499	0.4		0.08	6		
Independence St.	PSF	2007	6	27	2.6	26	7.6	7.8			0.26	0.099		0.1	19		
Independence St.	PSF	2007	7	24	1.5	19.5	6.4	8.2			0.0499	0.099		0.07	1.99		
Highway M	PSF	2007	8	28	3.5	23	8.4	7.7			0.0499	0.3		0.19	13		
Independence St.	PSF	2007	8	28	7.6	23	8.9	7.8			0.0499	1.1		0.16	33		
Highway M	PSF	2007	9	27	1.9	16.1	9.2	7.3			0.0499	0.099		0.13	10		
Independence St.	PSF	2007	9	27	2.5	15.8	8.1	7.4			0.0499	0.099		0.07	8		
Highway M	PSF	2007	10	24	1.5	10.3	9.7	7.5			0.0499	0.5		0.19	9		
Independence St.	PSF	2007	10	24	1.2	9.2	12.1	7.6			0.0499	0.6		0.18	14		
Highway M	PSF	2007	11	21	1.9	6.2	7.1	7.8			0.0499	0.099		0.13	4		
Independence St.	PSF	2007	11	21	1.01	7	8.7	7.8			0.0499	0.099		0.11	5		
Independence St.	PSF	2007	12	21	20.01	0		7.7			0.0499	0.9		0.18	33		
Highway M	PSF	2008	3	28	28.6	5		6.6			0.0499	0.2		0.07	15		
Independence St.	PSF	2008	3	28		4		6.6			0.0499	0.4			8		
Highway M	PSF	2008	4	30	8.4	9	10.1	6.6			0.0499	0.4		0.13	19		
Independence St.	PSF	2008	4	30		10	9.9	6.6			0.0499	0.5			40		
Highway M	PSF	2008	5	30	1602.8	18	7	6.1			0.0499	0.9		1.3	1716		
Independence St.	PSF	2008	5	30		17	9.5	6.2			0.0499	0.9			2170		
Highway M	PSF	2008	6	24	20.01	20	9.5	6.6			0.0499	0.3		0.1	12		
Independence St.	PSF	2008	6	24		21	10.1	6.7			0.0499	0.3			14		
Highway M	PSF	2008	7	31	300.5	23	5.9	6.9			0.14	0.099		0.21	71		
Independence St.	PSF	2008	7	31		23	6.2	7.4			0.1	0.2			163		
Highway M	PSF	2008	8	27	11.1	22	7.5	7.6			0.0499	0.2		0.1	1.99		

Site	Org.	Year	Month	Day	Flow	Temp	DO	pH	SC	KJN	NH3N	NO3N	TN	TP	TSS	TRB	CBOD
					cfs	deg C	mg/L		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU	mg/L
Independence St.	PSF	2008	8	27		19	8.3	6.4			0.0499	0.099			15		
Highway M	PSF	2008	9	30	25.01	13	10	7.3			0.0499	0.099		0.18	17		
Independence St.	PSF	2008	9	30		14	9.4	7.9			0.0499	0.099			10		
Highway M	PSF	2008	10	30	15.8	6.4	9.3	8			0.15	0.099		0.09	1.99		
Independence St.	PSF	2008	10	30		6.3	9	8.1			0.0499	0.2			4		
Highway M	PSF	2008	11	18	12.5	1	14.1	8			0.12	0.2		0.08	11		
Independence St.	PSF	2008	11	18		1	14	7.5			0.15	0.3			34		
Highway 6	MDNR	2009	2	18	13.6	2.6	11.5		494						43		
Highway 6	MDNR	2009	2	27	35	1.1	11.4	8.5	176						5190		
Highway 6	MDNR	2009	3	11	35	3	12	8.3	217						1780		
Highway 6	MDNR	2009	4	20	25	14.3	9.4	8.4	374						52		
Highway 6	MDNR	2009	5	6	20	17.8	9	8.3	453						88		
Highway 6	MDNR	2009	5	26	25	19.9	7.8	8.1	438						274		
Above Trenton WWTP	MDNR	2009	9	16	14	23.2	9.9	8.1	533	0.57	0.06	0.02499	0.59	0.08			0.99
Below Trenton WWTP	MDNR	2009	9	16	16.4	23.2	10.2	8.1	741	1.12	0.52	0.02499	1.14	0.31			3.22
Below Trenton WWTP	MDNR	2009	9	17			6.3	7.6	770	1.25	0.87	0.02499	1.27	0.66			3.81

Appendix A.2 – Muddy Creek Modeling Data

Collected by U.S. Environmental Protection Agency, August 24, 2009

Site	Site No.*	Time	Temp	SC	DO	pH	Alk	BOD_5	CHLa	NH3N	KJN	NO3N	TP	TSS	TOC	VSS	TRB
			deg C	µS/cm	mg/L		mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
Below Trenton WWTP	1(R)	9:30	19.6	399	8.07	5.09	147	<2.0	6.78	417	898	310	442	64	7.79	8	236
Below Trenton WWTP	1(C)	9:30	19.7	400	7.96	5.80	146	<2.0	7.42	371	946	310	480	58	8.10	8	93
Below Trenton WWTP	1(L)	9:30	19.6	400	8.19	5.87	146	<2.0	6.08	298	1090	310	498	51	8.03	8	93
28th St. Trenton Airport	2(R)	11:00	20.1	342	8.47	6.73	152	<2.0	7.28	135	774	200	192	60	7.70	11	96
28th St. Trenton Airport	2(C)	11:00	20.2	344	8.5	6.90	152	<2.0	6.66	148	756	180	189	61	7.71	12	102
28th St. Trenton Airport	2(L)	11:00	20.3	346	8.58	7.12	152	<2.0	6.66	110	738	160	205	59	7.67	7	141
Near Highway O	3(R)	12:15	22.9	362	8.17	7.35	160	<2.0	5.88	188	793	210	167	43	7.47	4	78
Near Highway O	3(C)	12:15	23.0	362	8.03	7.27	160	<2.0	5.08	166	713	180	168	44	7.49	6	96
Near Highway O	3(L)	12:15	23.0	362	8.49	7.32	160	<2.0	5.78	100	720	180	168	45	7.52	6	79
Highway B	4(C)	14:10	26.9	387	7.48	7.50				100	648	210	148		7.29	6	53
Imperial St.	5(C)	15:00	26.7	403	7.94	7.44				163	627	240	118		7.10	6	46

*(R), (L) and (C) refer to near right and left banks, and center of stream.

See additional notes and definitions of abbreviations for Appendix A on the following page.

Appendix A Notes and Abbreviations

Note: These data are of sufficient quality to evaluate compliance with water quality standards and to support TMDL development because they were collected in accordance with required quality assurance procedures and Department sampling protocols.

Empty cell means no data available.

Alk = Alkalinity
C = Temperature in degrees Celsius
BOD_5 = Biochemical Oxygen Demand, 5-day
CBOD = Carbonaceous Biochemical Oxygen Demand
CFS = Cubic feet per second
CHLa = Chlorophyll *a*
DO = Dissolved Oxygen
SC = Specific Conductivity
KJN = Kjeldahl Nitrogen
MDNR = Missouri Department of Natural Resources
µS/cm = Microsiemens per centimeter
mg/L = Milligrams per liter
NH3N = Ammonia as N
NO3N =Nitrate +nitrite as nitrogen
NTU = Nephelometric Turbidity Units
Org. = Organization
PSF = Premium Standard Farms
TN = Total Nitrogen
TOC = Total Organic Carbon
TP = Total Phosphorus
TSS = Total Suspended Solids
TRB = Turbidity
VSS = Volatile Suspended Solids
WWTP = Wastewater Treatment Plant

Detection limits and non-detects are expressed as "less-than" numbers and show up in this list as those data ending in 99. Example: <2 will appear as 0.99.

Appendix B

Suspended solids and instantaneous discharge for reference targeting

Data collected by USGS and provided by EPA

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Thompson River at Mount Moriah, MO					
6898100	11/9/1999	22	527		0.86
6898100	1/13/2000	8.6		0.7	E 0.04
6898100	3/23/2000	33			0.26
6898100	5/18/2000	19	27		0.14
6898100	7/13/2000	49			0.2
6898100	9/6/2000	10			0.53
6898100	11/28/2000	15	< 10	0.77	E 0.03
6898100	1/3/2001	7.5		0.75	< 0.06
6898100	3/15/2001	4860		5.6	1.92
6898100	5/2/2001	276	156	1.7	0.26
6898100	7/13/2001	126			0.16
6898100	9/20/2001	53		E 0.67	0.11
6898100	11/8/2001	41	14		E 0.06
6898100	1/17/2002	14	< 10	0.74	E 0.03
6898100	3/14/2002	91	43	1.9	0.1
6898100	5/9/2002	223	347	1.8	0.39
6898100	8/1/2002	26	30		0.12
6898100	9/3/2002	17	176		0.3
6898100	11/7/2002	18	< 10		0.05
6898100	1/15/2003	15	< 10		E 0.04
6898100	3/28/2003	50	11	0.68	0.07
6898100	5/22/2003	196	107	5.1	0.22
6898100	7/15/2003	76	66	1.4	0.28
6898100	8/29/2003	6.1	< 10		0.08
6898100	9/4/2003	10	146		0.34
6898100	11/4/2003	325	644	4	1.08
6898100	1/23/2004	23	< 10	0.82	E 0.04
6898100	3/25/2004	268	186	5	0.3
6898100	5/20/2004	E 837	593	7.6	1.03
6898100	7/9/2004	118	17	2.8	0.28
6898100	9/10/2004	259	82	1.2	0.26
6898100	11/8/2004	70	132		0.24
6898100	1/21/2005	31	< 10	0.95	E 0.03
6898100	3/3/2005	144	42	2.4	0.09
6898100	5/25/2005	342	292	3.8	0.39
6898100	7/8/2005	96	67		0.19
6898100	9/16/2005	23	< 10	E 0.32	0.05
6898100	11/10/2005	12	< 10		0.04
6898100	1/20/2006	23	< 10		0.04
6898100	3/31/2006	23	< 10		0.04
6898100	5/25/2006	81	100		0.22

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6898100	7/27/2006	15	23		0.1
6898100	9/8/2006	44	28		0.13
6898100	11/9/2006	23	< 10		0.05
6898100	1/4/2007	381	333	7.4	0.77
6898100	2/14/2007	24	< 10	3.9	E 0.03
6898100	3/21/2007	291	218	3.4	0.32
6898100	4/6/2007	394	192	3.2	0.3
6898100	5/23/2007	298	63	3.3	0.17
6898100	6/20/2007	133	82	2.1	0.18
6898100	7/25/2007	54	17		0.09
6898100	9/19/2007	132	26	E 0.83	0.1
6898100	11/16/2007	137	48	2.1	0.14
6898100	1/24/2008	200	20	2.4	0.07
6898100	3/12/2008	682	328	2.9	0.55
6898100	5/29/2008	481	196	3.4	0.29
6898100	7/10/2008	1280	1440	5.2	1.52
6898100	9/17/2008	569	300	1.7	0.43
6898100	10/22/2008	1380	2930	5.2	2.44
6898100	1/14/2009	235	74	1.7	0.09
6898100	3/5/2009	264	254	2.2	0.35
6898100	5/7/2009	614	336	3.1	0.45
6898100	7/16/2009	1220	718	3.2	0.64
6898100	9/3/2009	288	109	1.2	0.25
Weldon River near Princeton, MO					
6898800	11/9/1999	5.3		0.29	0.043
6898800	1/11/2000	10		0.38	< 0.05
6898800	3/21/2000	13			E 0.03
6898800	5/16/2000	2.4	< 10		< 0.05
6898800	7/11/2000	9.4			0.09
6898800	9/6/2000	1.8			0.07
6898800	11/30/2000	5.2	< 10	0.6	< 0.060
6898800	1/5/2001	8.1		0.54	< 0.06
6898800	3/15/2001	2840		3.9	1.28
6898800	5/2/2001	152	119	2.5	0.24
6898800	7/11/2001	63			0.13
6898800	9/18/2001	18		E 0.35	< 0.06
6898800	11/6/2001	36	18	0.6	0.1
6898800	1/15/2002	20	< 10	0.57	< 0.06
6898800	3/12/2002	101	114	2.6	0.21
6898800	5/7/2002	527	210	2.3	0.5
6898800	7/30/2002	17	14		0.07
6898800	8/15/2002	8.7	20		0.07
6898800	9/5/2002	3.3	13		E 0.04
6898800	10/24/2002	5	< 10	E 0.34	E 0.03
6898800	11/5/2002	6.5	< 10		< 0.04

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6898800	12/10/2002	4.3	< 10	E 0.29	E 0.02
6898800	1/14/2003	1.9	< 10		E 0.02
6898800	3/7/2003	8.6	< 10	0.64	E 0.03
6898800	3/26/2003	7.3	< 10		0.04
6898800	5/20/2003	168	264	1.7	0.33
6898800	7/17/2003	6.1	19		0.08
6898800	9/5/2003	0.73	52		< 0.04
6898800	11/6/2003	99	120	4.5	0.5
6898800	1/21/2004	30	19	2.5	0.13
6898800	3/23/2004	90	39	1.7	0.12
6898800	5/18/2004	473	267	15	1.73
6898800	7/7/2004	44	14		0.08
6898800	9/8/2004	166	85	0.86	0.2
6898800	11/10/2004	20	< 10	E 0.35	E 0.03
6898800	1/19/2005	11	< 10	0.59	< 0.04
6898800	3/1/2005	80	51	1.1	0.07
6898800	5/23/2005	128	266	2.2	0.34
6898800	7/6/2005	23	< 10		E 0.04
6898800	9/14/2005	6	10		0.05
6898800	11/8/2005	6.5	21		0.04
6898800	1/18/2006	9.4	< 10		< 0.04
6898800	3/31/2006	117	750	3	0.8
6898800	5/23/2006	6.1	12		0.04
6898800	7/25/2006	1.5	60		0.11
6898800	9/6/2006	9.2	42		0.08
6898800	11/7/2006	5.5	< 10		0.06
6898800	1/4/2007	82	44	3.7	0.23
6898800	2/16/2007	7.2	< 10	0.42	E 0.03
6898800	3/23/2007	625	1250	5.5	1.52
6898800	4/6/2007	174	86	1.4	0.15
6898800	5/23/2007	97	28	1	0.09
6898800	6/20/2007	35	31		0.12
6898800	7/25/2007	19	15		0.07
6898800	9/19/2007	42	24		0.07
6898800	11/14/2007	24	13	E 0.46	0.06
6898800	1/24/2008	60	140	1.6	0.26
6898800	3/12/2008	615	472	1.9	0.48
6898800	5/29/2008	166	79	1.2	0.17
6898800	7/10/2008	307	426	2.8	0.6
6898800	9/17/2008	325	364	1.4	0.41
6898800	10/22/2008	6480	1850	4.9	1.93
6898800	1/14/2009	78	< 15	0.92	E 0.04
6898800	3/6/2009	121	112	0.76	0.14
6898800	5/7/2009	260	126	1.2	0.21
6898800	7/16/2009	98	54		0.16

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6898800	9/3/2009	274	145	1.1	0.26
No. Creek near Dunlap					
6899580	1/22/1998	3.7	1		
6899580	6/2/1998	3.2	51		
6899580	3/30/1999	4.4		0.48	E 0.05
6899580	4/22/1999	14		0.77	0.13
6899580	6/21/1999	0.25	70		0.14
6899580	10/25/1999	0.01		8.6	0.19
6899580	11/29/1999	0.01	73		0.24
6899580	12/20/1999	0.1			0.09
6899580	1/24/2000	0.1	28	1.4	0.12
6899580	2/23/2000	0.06			0.14
6899580	4/20/2000	0.81			0.16
6899580	5/9/2000	0.17	54	6.7	0.3
6899580	6/14/2000	6.4		6.3	0.46
6899580	6/22/2000	0.4		1.3	0.18
6899580	7/25/2000	0.11	45	1.4	0.15
6899580	10/24/2000	0.37		1.6	0.67
6899580	11/15/2000	0.68	21	2.1	0.14
6899580	12/19/2000	0.08		E 1.4	E 0.06
6899580	1/24/2001	1.6	18	2.9	0.1
6899580	2/15/2001	40		2.8	0.34
6899580	3/27/2001	10		1.6	0.12
6899580	4/24/2001	19		1.3	0.18
6899580	5/22/2001	9.9	41	1.3	0.15
6899580	6/19/2001	2.7		1.6	0.23
6899580	6/25/2001	5.2		1.1	0.18
6899580	7/26/2001	59	290	1.7	0.35
6899580	8/9/2001	0.47		E 0.75	0.12
6899580	9/13/2001	0.1		E 2.4	0.15
6899580	10/23/2001	38	386	2.3	0.72
6899580	11/29/2001	0.28	78		0.19
6899580	12/13/2001	1	20		0.1
6899580	2/28/2002	1.7	22	1.2	0.07
6899580	3/21/2002	2.1	< 10		E 0.03
6899580	4/18/2002	4.3	36	0.75	0.12
6899580	5/23/2002	2.4	< 10	E 0.51	0.07
6899580	6/13/2002	0.53	20	0.64	0.1
6899580	6/28/2002	0.07	40		0.11
6899580	7/23/2002	0.01	< 10	E 8.0	0.17
6899580	8/22/2002	1	44	7.3	0.91
6899580	12/19/2002	0.01	37		0.16
6899580	3/13/2003	0.41	< 10		0.17
6899580	3/20/2003	0.34	12		0.15
6899580	4/25/2003	2.1	82	1.2	0.22

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899580	4/30/2003	0.62	12		0.14
6899580	5/6/2003	6.4	164	3.5	0.38
6899580	6/12/2003	3	68	8.2	0.24
6899580	7/9/2003	0.01	43	4.9	0.27
6899580	9/19/2003	0.26	144	1.1	0.28
6899580	10/23/2003	0.03	70		0.28
6899580	11/18/2003	0.1	23		0.22
6899580	12/11/2003	22	120	3.7	0.43
6899580	1/8/2004	1	17	2.3	0.11
6899580	2/27/2004	5.8	14	1.9	0.11
6899580	3/18/2004	52	117	2	0.25
6899580	4/20/2004	2.7	33		0.1
6899580	5/11/2004	1.3	< 10		0.08
6899580	6/22/2004	9.1	49	1.1	0.17
6899580	7/16/2004	0.41	23	E 0.78	0.14
6899580	8/23/2004	0.72	67	E 0.77	0.14
6899580	9/14/2004	0.76	520	E 2.6	0.79
6899580	10/26/2004	1	< 10		0.28
6899580	11/16/2004	3.7	< 10	0.46	0.06
6899580	12/14/2004	6.2	18	0.65	0.08
6899580	1/25/2005	0.08	18	1.2	0.14
6899580	2/10/2005	21	138	1.4	0.16
6899580	3/17/2005	2.9	< 10		E 0.04
6899580	4/5/2005	3.6	< 10		0.04
6899580	5/12/2005	2	52		0.14
6899580	6/30/2005	0.86	24	0.73	0.12
6899580	7/13/2005	0.03	< 10		0.06
6899580	8/19/2005	0.02	33		0.09
6899580	9/21/2005	0.05	53		0.12
6899580	10/5/2005	0.08	380		0.49
6899580	11/3/2005	0.01	1510		1.94
6899580	12/14/2005	0.1	44	E 1.5	0.19
6899580	1/25/2006	0.03	43		0.11
6899580	2/14/2006	0.01	22		0.1
6899580	3/9/2006	0.2	< 10		0.07
6899580	4/12/2006	2.1	72	0.95	0.16
6899580	5/9/2006	2.8	44	0.93	0.13
6899580	6/15/2006	0.23	24	5.8	0.13
6899580	7/19/2006	0	152		0.59
6899580	8/10/2006	3.1	147	1.6	0.34
6899580	9/21/2006	0.02	170	E 4.3	0.31
6899580	10/25/2006	0.02	93	E 2.1	0.35
6899580	12/13/2006	0.52	17	0.92	0.12
6899580	1/26/2007	0.84	< 10	1	E 0.04
6899580	2/20/2007	56	162	3.8	0.68

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899580	3/15/2007	8.1	37	1.2	0.09
6899580	4/27/2007	76	225	2.9	0.38
6899580	5/10/2007	18	110	2.7	0.23
6899580	6/28/2007	19	485	7.6	0.64
6899580	7/19/2007	E 0.03	165	E 1.3	0.21
6899580	8/23/2007	0.24	75	1.5	0.21
6899580	9/27/2007	0.19	105		0.25
6899580	10/16/2007	0.06	136	E 1.2	0.36
6899580	11/8/2007	0.01	16		0.28
6899580	12/20/2007	3.1	20	2.2	0.14
6899580	1/10/2008	22	58	2	0.23
6899580	2/26/2008	E 65	86	2.9	0.35
6899580	3/25/2008	8.3	34	0.95	0.1
6899580	4/16/2008	11	102	1.2	0.18
6899580	5/22/2008	2.1	138	E 1.0	0.22
6899580	6/17/2008	13	74	1.3	0.22
6899580	7/15/2008	0.8	46	1.1	0.14
6899580	8/12/2008	0.55	24	E 0.54	0.1
6899580	9/23/2008	3	< 10	0.44	0.09
6899580	10/28/2008	6.6	< 15	0.65	0.13
6899580	11/18/2008	11	< 15	0.65	0.1
6899580	12/2/2008	5.8	< 15	0.54	0.07
6899580	1/27/2009	1.9	< 15	E 0.34	E 0.04
6899580	2/24/2009	3	16		0.05
6899580	3/12/2009	16	250	2.1	0.34
6899580	4/24/2009	6.5	16	E 0.48	0.08
6899580	5/15/2009	29	730	2.7	0.65
6899580	6/23/2009	20	< 150	1.8	0.27
6899580	8/18/2009	56	266	2	0.38
No Creek at Farmersville, MO					
6899585	11/16/2006	0.13	< 10	0.44	0.26
Medicine Creek near Harris, MO					
6899950	10/26/1999	2.3			E 0.045
6899950	11/30/1999	3	6		< 0.05
6899950	12/21/1999	0.1		0.65	< 0.05
6899950	1/25/2000	0.5	3		< 0.05
6899950	2/22/2000	15			E 0.04
6899950	3/27/2000	8.7			E 0.03
6899950	4/18/2000	4			E 0.03
6899950	5/10/2000	10	< 10		0.05
6899950	6/21/2000	6		0.87	0.08
6899950	7/26/2000	6.6	37		0.11
6899950	9/20/2000	3.4		0.54	0.07
6899950	10/26/2000	6.1			0.07
6899950	11/14/2000	5.8	< 10	0.93	0.09

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899950	12/18/2000	3.1		E 0.34	< 0.06
6899950	1/25/2001	12	< 10	3.2	0.11
6899950	2/13/2001	131		2.8	0.3
6899950	3/29/2001	100		2	0.21
6899950	4/26/2001	76		1	0.21
6899950	5/24/2001	52	68	1.3	0.18
6899950	6/19/2001	79		1.5	0.33
6899950	6/26/2001	60		1.1	0.18
6899950	7/25/2001	353	1610	3.2	1.34
6899950	8/8/2001	13		E 0.55	0.09
6899950	9/12/2001	7.4		0.5	0.07
6899950	10/25/2001	33	118	2.6	0.37
6899950	11/28/2001	3.4	12	E 0.35	E 0.03
6899950	12/12/2001	6.2			< 0.06
6899950	1/3/2002	4.6	< 10	0.55	< 0.06
6899950	1/8/2002	5	< 10	E 0.45	< 0.06
6899950	2/27/2002	9.9	12	1.3	0.07
6899950	3/19/2002	18	< 10		0.06
6899950	4/17/2002	68	130	1.4	0.24
6899950	5/21/2002	38	38	1	0.1
6899950	6/28/2002	5.6	13		E 0.06
6899950	7/24/2002	3.6	< 10		0.08
6899950	8/21/2002	17	41		0.14
6899950	9/10/2002	1.4	< 10		E 0.05
6899950	10/17/2002	1.4	< 10		E 0.03
6899950	11/19/2002	2	< 10		E 0.03
6899950	12/18/2002	2.8	< 10		0.04
6899950	1/30/2003	0.9	< 10		E 0.03
6899950	2/20/2003	3.4	< 10		E 0.03
6899950	3/12/2003	3.9	< 10		0.1
6899950	4/23/2003	14	12		0.25
6899950	5/8/2003	27	104	2.9	0.29
6899950	6/11/2003	51	282	5.8	0.47
6899950	7/10/2003	65	161	1.5	0.3
6899950	8/25/2003	0.61	< 10		0.06
6899950	9/17/2003	4.5	49	1.4	0.36
6899950	10/22/2003	1.3	< 10		0.05
6899950	11/20/2003	3	< 10		0.06
6899950	12/10/2003	368	E 692	5.5	2.81
6899950	1/7/2004	6.2	< 10	1.7	0.06
6899950	2/26/2004	55	66	2.4	0.34
6899950	3/16/2004	71	53	1.7	0.22
6899950	4/22/2004	21	12		0.06
6899950	5/13/2004	11	< 10		0.05
6899950	6/23/2004	42	49	1.2	0.18

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899950	7/14/2004	32	76	1.3	0.24
6899950	8/25/2004	378	1700	4.9	1.77
6899950	9/16/2004	25	15		0.1
6899950	10/27/2004	50	131	1.5	0.31
6899950	11/18/2004	16	< 10		0.04
6899950	12/16/2004	26	< 10	0.82	0.05
6899950	1/27/2005	169	280	2.3	0.53
6899950	2/9/2005	105	165	2.2	0.25
6899950	3/16/2005	28	< 10		0.06
6899950	4/8/2005	77	79		0.21
6899950	5/11/2005	24	15		0.08
6899950	6/29/2005	77	620	5.6	1.27
6899950	7/12/2005	5.7	< 10		0.05
6899950	8/17/2005	6.2	< 10	0.71	0.06
6899950	9/20/2005	3.6	14	E 0.37	0.05
6899950	10/5/2005	2.8	11		0.04
6899950	11/2/2005	2	< 10		E 0.03
6899950	12/15/2005	4.4	< 10		E 0.02
6899950	1/26/2006	2.6	< 10		E 0.03
6899950	2/17/2006	1.3	< 10		0.04
6899950	3/8/2006	9.8	< 10		0.06
6899950	4/13/2006	12	15		0.08
6899950	5/10/2006	18	20	0.59	0.07
6899950	6/14/2006	2.4	< 10		0.04
6899950	7/18/2006	4.8	16		0.13
6899950	8/9/2006	16	150	1.5	0.38
6899950	9/20/2006	1.4	< 10		< 0.04
6899950	10/24/2006	3	< 10		0.08
6899950	11/15/2006	2.6	< 10		0.09
6899950	12/14/2006	4.4	24	1.5	0.07
6899950	1/25/2007	8	< 10	1.3	0.06
6899950	2/21/2007	460	379	7.4	1.37
6899950	3/14/2007	60	72	2	0.2
6899950	4/27/2007	971	660	4.5	1.19
6899950	5/9/2007	349	424	2.8	0.63
6899950	6/27/2007	10	19	0.65	0.08
6899950	7/18/2007	4.6	10		0.08
6899950	8/21/2007	57	763	3.2	0.93
6899950	9/25/2007	9.8	< 20		0.08
6899950	10/16/2007	46	84	1.2	0.25
6899950	11/6/2007	14	< 10	0.49	0.09
6899950	12/19/2007	57	35	1.7	0.13
6899950	1/9/2008	483	406	2.6	0.56
6899950	2/27/2008	202	140	3.5	0.45
6899950	3/26/2008	64	49	0.97	0.12

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6899950	4/16/2008	119	170	1.5	0.27
6899950	5/21/2008	36	19		0.1
6899950	6/18/2008	112	148	1.4	0.28
6899950	7/16/2008	19	35		0.14
6899950	8/13/2008	25	46		0.1
6899950	9/24/2008	98	536	2.6	0.61
6899950	10/29/2008	60	39	0.92	0.17
6899950	11/19/2008	75	42	0.83	0.12
6899950	12/3/2008	49	16	0.61	0.06
6899950	1/28/2009	19	< 15	0.72	0.04
6899950	2/25/2009	34	22	0.61	0.06
6899950	3/11/2009	715	1180	4.9	1.37
6899950	4/22/2009	61	85	0.92	0.17
6899950	5/13/2009	377	1900	6.5	2.37
6899950	6/24/2009	75	220	2.4	0.42
6899950	7/22/2009	20	24		0.1
6899950	8/20/2009	180	455	2.2	0.54
Little Medicine Creek near Harris					
6900100	1/22/1998	8.7	1		
6900100	6/2/1998	11	26		
6900100	1/5/1999	4.8	5	0.67	< 0.05
6900100	3/31/1999	12		0.37	E 0.03
6900100	4/21/1999	35		1.1	0.16
6900100	6/22/1999	4.7	30	0.97	0.11
6900100	8/25/1999	0.62		0.56	E 0.04
6900100	10/26/1999	0.67			E 0.03
6900100	11/30/1999	0.73	1		< 0.05
6900100	12/21/1999	0.1		0.82	0.06
6900100	1/25/2000	0.5	4		< 0.05
6900100	2/22/2000	1.8			E 0.04
6900100	3/27/2000	1.1			< 0.05
6900100	4/18/2000	2			E 0.04
6900100	5/10/2000	1.4	< 10		E 0.03
6900100	6/21/2000	1.2		1.5	0.07
6900100	7/26/2000	1.6	< 10		0.07
6900100	9/20/2000	1.6			0.05
6900100	10/26/2000	1.8			0.08
6900100	11/14/2000	1.8	< 10	1	E 0.06
6900100	12/19/2000	0.91		0.44	E 0.04
6900100	1/25/2001	3.2	< 10	3.2	E 0.04
6900100	2/13/2001	46		3.2	0.42
6900100	3/29/2001	35		1.9	0.14
6900100	4/26/2001	18		0.87	0.15
6900100	5/24/2001	16	31	1.4	0.12
6900100	6/19/2001	17		1.9	0.26

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6900100	6/26/2001	13		0.92	0.09
6900100	7/25/2001	11	444	4	0.48
6900100	8/8/2001	1.4		0.59	E 0.05
6900100	9/12/2001	1.2		0.79	0.07
6900100	10/25/2001	7.5	54	2.2	0.2
6900100	11/28/2001	1.5	< 10		< 0.06
6900100	12/12/2001	1.7	< 10		< 0.06
6900100	1/8/2002	0.38	< 10	0.8	< 0.06
6900100	2/27/2002	1.8	< 10	1.2	E 0.03
6900100	3/19/2002	2	< 10		< 0.06
6900100	4/17/2002	13	66	1	0.13
6900100	5/21/2002	9.1	14	0.67	0.07
6900100	6/28/2002	2	< 10	E 0.44	E 0.04
6900100	7/24/2002	0.59	< 10		E 0.04
6900100	8/21/2002	3.1	< 10	0.62	0.1
6900100	9/10/2002	0.15	< 10		E 0.04
6900100	10/17/2002	0.31	< 10		E 0.03
6900100	11/19/2002	0.41	< 10		0.06
6900100	12/18/2002	0.64	< 10		E 0.02
6900100	1/29/2003	0.11	< 10		0.05
6900100	2/20/2003	0.64	< 10		E 0.03
6900100	3/12/2003	1.4	< 10		< 0.04
6900100	4/23/2003	0.47	< 10	0.61	0.04
6900100	5/8/2003	3.5	127	2.4	0.19
6900100	6/11/2003	30	344	5.4	0.51
6900100	7/10/2003	138	E 2060	7.7	1.76
6900100	8/25/2003	0.08	13	E 0.64	0.1
6900100	9/18/2003	0.48	20	0.65	0.07
6900100	10/22/2003	0.3	< 10		0.07
6900100	11/20/2003	0.52	< 10		0.05
6900100	12/10/2003	98	470	6.5	0.93
6900100	1/7/2004	0.73	16	2.2	E 0.03
6900100	2/26/2004	10	36	2.2	0.11
6900100	3/16/2004	25	56	1.7	0.14
6900100	4/22/2004	4.6	< 10		0.04
6900100	5/13/2004	8.9	102	1.2	0.18
6900100	6/23/2004	12	33	1.3	0.13
6900100	7/14/2004	6	37	1.3	0.15
6900100	8/25/2004	2150	1400	5.8	1.91
6900100	9/16/2004	5.8	64	0.65	0.17
6900100	10/27/2004	16	146	1.3	0.29
6900100	11/18/2004	5.2	< 10		E 0.04
6900100	12/17/2004	4.6	< 10	0.85	E 0.03
6900100	1/27/2005	24	51	2.6	0.37
6900100	2/10/2005	7	48	1.8	0.11

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6900100	3/16/2005	7.6	< 10		0.04
6900100	4/8/2005	15	18		0.07
6900100	5/12/2005	8.6	38	E 0.66	0.1
6900100	6/30/2005	6	20	E 0.73	0.1
6900100	7/12/2005	1.4	< 10	E 0.53	0.06
6900100	8/17/2005	0.42	< 10	0.64	0.06
6900100	9/20/2005	0.64	< 10		0.05
6900100	10/5/2005	0.22	< 10	E 0.29	E 0.04
6900100	11/2/2005	0.15	< 10		0.05
6900100	12/15/2005	1.6	< 10		E 0.03
6900100	1/26/2006	0.73	< 10		E 0.03
6900100	2/17/2006	0.37	< 10		E 0.04
6900100	3/8/2006	2.2	< 10		0.04
6900100	4/13/2006	1.5	15		0.07
6900100	5/10/2006	2.3	19		0.05
6900100	6/14/2006	0.43	< 10	0.53	0.05
6900100	7/19/2006	0.22	< 10	0.79	0.08
6900100	8/9/2006	3	122	1.2	0.25
6900100	9/20/2006	0.16	< 10		E 0.03
6900100	10/24/2006	0.35	< 10		0.06
6900100	11/16/2006	0.45	< 10		0.09
6900100	12/14/2006	1.1	13	1.5	0.06
6900100	1/25/2007	2.2	< 10	1.2	< 0.04
6900100	2/21/2007	E 130	59	6.2	1.16
6900100	3/15/2007	14	64	1.8	0.13
6900100	4/25/2007	1830	1070	7.3	2.42
6900100	5/10/2007	52	184	2.3	0.33
6900100	6/27/2007	1.4	10	0.56	0.06
6900100	7/18/2007	0.53	13		0.06
6900100	8/21/2007	14	663	5.6	0.92
6900100	9/25/2007	1.5	< 20	E 0.43	0.09
6900100	10/17/2007	13	424	2.2	0.81
6900100	11/8/2007	1	< 10		0.1
6900100	12/19/2007	13	31	2.2	0.15
6900100	1/10/2008	68	88	2.7	0.34
6900100	2/27/2008	58	82	3.2	0.37
6900100	3/26/2008	21	43	0.95	0.11
6900100	4/16/2008	33	88	1.4	0.21
6900100	5/21/2008	7.3	< 10		0.08
6900100	6/18/2008	20	74	1.3	0.21
6900100	7/16/2008	3	10	0.51	0.07
6900100	8/13/2008	3.3	13	0.48	0.08
6900100	9/24/2008	300	2200	5.7	1.81
6900100	10/29/2008	18	23	0.65	0.11
6900100	11/19/2008	30	33	1	0.11

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6900100	12/3/2008	17	< 15	0.68	0.05
6900100	1/28/2009	4.5	< 15	0.73	E 0.03
6900100	2/25/2009	12	18	0.57	0.05
6900100	3/11/2009	118	490	3.4	0.56
6900100	4/22/2009	15	15	0.41	0.06
6900100	5/13/2009	352	1760	7.8	2.21
6900100	6/24/2009	26	160	2	0.29
6900100	7/22/2009	2.5	< 15	0.47	0.05
6900100	8/20/2009	176	1290	3.8	1.15
Locust Creek near Linneus, MO					
6901500	8/26/2003	0.8	<10		0.05
Grand River near Sumner, MO					
6902000	11/8/1989	373		1	0.13
6902000	1/18/1990	851		2.2	0.34
6902000	5/9/1990	5480		2.3	0.42
6902000	7/11/1990	1430		1.3	0.35
6902000	11/7/1990	1310		3.6	0.3
6902000	1/9/1991	452		2	0.24
6902000	5/17/1991	14200		2.6	0.39
6902000	7/16/1991	2510		3.2	0.41
6902000	11/6/1991	470		1.7	0.31
6902000	1/15/1992	2720		1.7	0.34
6902000	7/8/1992	340			0.11
6902000	11/12/1992	7780		2.2	0.22
6902000	12/2/1992	4980		1.4	0.28
6902000	1/6/1993	8980		1.9	0.47
6902000	2/17/1993	2510		1.4	0.25
6902000	3/17/1993	3220		1.5	0.28
6902000	4/8/1993	29800		1.5	0.22
6902000	5/12/1993	33700		3.7	0.2
6902000	6/16/1993	18400		11	1
6902000	7/27/1993	128000		2.1	0.55
6902000	8/25/1993	2820		1.3	
6902000	9/16/1993	23600		2.8	0.34
6902000	10/27/1993	1700		1.1	0.04
6902000	11/16/1993	3300		1.7	0.25
6902000	12/8/1993	1140			0.03
6902000	1/5/1994	755		0.92	0.05
6902000	2/3/1994	1200		2.7	0.18
6902000	3/16/1994	1750		1.8	0.18
6902000	3/30/1994	750		0.78	0.09
6902000	4/27/1994	900			0.12
6902000	5/10/1994	3700		2.6	0.28
6902000	6/14/1994	4500		5.2	1.2
6902000	8/23/1994	250			

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6902000	9/14/1994	270			0.11
6902000	10/26/1994	136			0.13
6902000	11/30/1994	1200		2	0.15
6902000	12/14/1994	1140		1.8	0.2
6902000	1/5/1995	350		1.4	0.03
6902000	2/8/1995	2060		2.7	0.27
6902000	3/30/1995	2720		3.5	0.13
6902000	4/18/1995	5660		7.9	0.41
6902000	5/24/1995	51600		2.8	0.4
6902000	6/14/1995	4450		1.5	0.2
6902000	7/12/1995	6100		2.8	0.14
6902000	8/2/1995	2030		1.8	0.39
6902000	9/5/1995	496			0.13
6902000	10/24/1995	235			0.11
6902000	11/6/1995	595		1.2	0.1
6902000	12/13/1995	216		0.49	0.04
6902000	1/22/1996	430		1.1	0.08
6902000	2/14/1996	3050		2.5	1
6902000	3/26/1996	1480		2.4	0.31
6902000	4/16/1996	520			0.16
6902000	5/20/1996	4660		3.6	0.57
6902000	6/19/1996	14500		4.8	0.83
6902000	7/17/1996	1050			0.16
6902000	8/14/1996	906			0.12
6902000	9/11/1996	1170		1.6	0.14
6902000	10/9/1996	527			0.1
6902000	11/20/1996	4930		3.3	0.18
6902000	1/22/1997	466		1.4	0.07
6902000	2/12/1997	1620		2.2	0.16
6902000	3/17/1997	2510		1.7	0.28
6902000	4/23/1997	29800		4.6	0.28
6902000	5/27/1997	2130		E 2.9	0.44
6902000	6/17/1997	15100		5.2	0.25
6902000	7/29/1997	395			0.12
6902000	8/19/1997	511		0.98	0.18
6902000	9/9/1997	286		1.2	0.15
6902000	11/17/1997	415	6		
6902000	1/15/1998	1590	16		
6902000	6/9/1998	4290	452		
6902000	8/18/1998	587	60		
6902000	11/16/1998	4640	264	1.3	0.15
6902000	12/1/1998	6620		2.4	0.8
6902000	1/25/1999	4150	231	2.4	0.31
6902000	2/23/1999	3040		1.2	0.16
6902000	3/23/1999	2740		3.2	0.25

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6902000	4/13/1999	3460		2.5	0.47
6902000	5/19/1999	31900		2.5	0.7
6902000	6/15/1999	6840	1800		
6902000	7/27/1999	429			0.17
6902000	8/10/1999	639	80		0.22
6902000	9/13/1999	365			0.21
6902000	10/26/1999	130			0.1
6902000	11/30/1999	240	10		< 0.05
6902000	12/21/1999	157		0.83	0.06
6902000	1/4/2000	198	16	0.75	0.07
6902000	2/1/2000	123		0.61	0.05
6902000	3/7/2000	565		1.7	0.27
6902000	4/3/2000	301		0.83	0.19
6902000	5/2/2000	308	95		0.22
6902000	6/12/2000	217			0.22
6902000	7/11/2000	924	180	1.3	0.32
6902000	8/2/2000	465			0.23
6902000	9/12/2000	129			0.22
6902000	10/2/2000	341			0.28
6902000	11/21/2000	220	12	1.2	0.08
6902000	12/5/2000	207		1.3	0.08
6902000	1/3/2001	E 203	< 10	1.5	E 0.03
6902000	2/14/2001	5880		3.3	0.53
6902000	3/6/2001	8040		3.8	0.79
6902000	4/17/2001	7800		3	0.76
6902000	5/1/2001	1740	90		0.22
6902000	6/19/2001	6690		4.7	1.33
6902000	7/10/2001	1830	174	1.2	0.26
6902000	8/13/2001	572			0.17
6902000	9/5/2001	404			0.17
6902000	10/17/2001	3210	555	2.4	0.65
6902000	11/6/2001	416	18		0.1
6902000	12/4/2001	323	16	0.46	0.12
6902000	1/8/2002	179	< 10	0.61	E 0.05
6902000	2/5/2002	347	12	0.95	0.08
6902000	3/6/2002	573	12	0.99	E 0.05
6902000	4/10/2002	4220	1440	3.8	1.16
6902000	5/7/2002	43700	2420	9.1	3.12
6902000	6/10/2002	841			0.2
6902000	7/16/2002	393	145	1.8	0.54
6902000	8/13/2002	175	< 10		0.17
6902000	9/4/2002	145	65		0.18
6902000	10/22/2002	97	39		0.11
6902000	11/27/2002	115	10		0.07
6902000	12/12/2002	102	< 10	0.45	0.05

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6902000	2/12/2003	121	< 10	1.3	0.06
6902000	2/25/2003	E 130	< 10	0.52	0.08
6902000	3/21/2003	354	29	0.9	0.09
6902000	4/11/2003	163	46		0.12
6902000	5/2/2003	1940	524	3.3	0.76
6902000	6/20/2003	516	114	2	0.28
6902000	7/29/2003	130	19		0.19
6902000	8/21/2003	66	81		0.23
6902000	9/9/2003	85	58		0.18
6902000	10/21/2003	96	44		0.2
6902000	11/5/2003	75	26		0.09
6902000	12/15/2003	888	89	3.1	0.32
6902000	1/7/2004	E 275	< 10	1.6	0.08
6902000	2/3/2004	E 165	< 10	1.4	0.08
6902000	3/2/2004	997	112	2.8	0.26
6902000	4/6/2004	2040	136	2.4	0.25
6902000	5/19/2004	21000	1070	8.8	2.37
6902000	6/28/2004	1910	158	1.3	0.28
6902000	7/15/2004	7510	475	3.8	1.22
6902000	8/16/2004	715	49		0.19
6902000	9/2/2004	E 125000	543	1.7	0.57
6902000	10/12/2004	900	132	1.3	0.26
6902000	11/9/2004	1410	56	0.93	0.17
6902000	12/1/2004	813	22	0.86	0.11
6902000	1/24/2005	1530	90	1.8	0.22
6902000	2/14/2005	55000	2160	6.4	1.83
6902000	3/8/2005	1460	43	1.2	0.12
6902000	4/4/2005	992	55		0.11
6902000	5/3/2005	1530	117	1.7	0.21
6902000	6/22/2005	1600	203	1.8	0.34
6902000	7/12/2005	513	135		0.26
6902000	8/22/2005	909	252	1.9	0.41
6902000	9/7/2005	301	55		0.18
6902000	10/12/2005	315	34	1.1	0.12
6902000	11/2/2005	220	< 10	0.54	0.07
6902000	12/19/2005	272	< 10	1	0.04
6902000	1/4/2006	459	14	1.1	0.07
6902000	2/7/2006	357	< 10	0.79	0.07
6902000	3/7/2006	267	12	E 0.44	0.07
6902000	4/10/2006	1010	415	2.7	0.53
6902000	5/3/2006	12500	1180	7.1	1.48
6902000	6/21/2006	386	154		0.3
6902000	7/6/2006	259	41		0.2
6902000	8/2/2006	131	138		0.23
6902000	9/6/2006	432	170		0.34

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6902000	10/10/2006	121	51		0.1
6902000	11/6/2006	289	43	1.2	0.15
6902000	12/5/2006	546	76	2.8	0.26
6902000	1/4/2007	3400	767	4.9	1.05
6902000	2/14/2007	272	< 10	1.6	0.05
6902000	3/7/2007	3450	258	3.4	0.48
6902000	4/3/2007	7510	1120	3.9	1.1
6902000	5/2/2007	4620	360	3.4	0.51
6902000	6/6/2007	4600	200	3.1	0.43
6902000	7/10/2007	447	104		0.2
6902000	8/14/2007	1230	242	2	0.37
6902000	9/11/2007	736	52		0.17
6902000	10/23/2007	3100	340	2.9	0.6
6902000	11/6/2007	569	27	1.5	0.12
6902000	12/4/2007	702	45	0.84	0.14
6902000	1/9/2008	16000	850	3.9	1.11
6902000	2/14/2008	1900	100	1.9	0.22
6902000	3/5/2008	50600	1180	3.9	1.43
6902000	4/16/2008	7050	144	2.8	0.64
6902000	6/2/2008	10700	1120	5.1	1.31
6902000	7/9/2008	4230	384	1.8	0.49
6902000	8/4/2008	8200	452	1.7	0.47
6902000	9/2/2008	803	80		0.16
6902000	10/21/2008	1940	106	1.4	0.27
6902000	11/24/2008	2600	75	1.1	0.15
6902000	12/9/2008	1500	48	0.94	0.11
6902000	2/2/2009	1080	< 15	1	0.06
6902000	3/10/2009	57300	1300	5.9	1.77
6902000	4/1/2009	10900	418	2.3	0.55
6902000	5/5/2009	8690	780	2.5	0.68
6902000	6/2/2009	3960	312	2.9	0.42
6902000	7/28/2009	986	62		0.18
6902000	8/17/2009	46900	1790	3.9	1.52
6902000	9/1/2009	6300	454	1.7	0.53
Mussel fork near Mystic, MO					
6905725	1/23/1998	1.6	12		
6905725	6/3/1998	1.2	22		
6905725	1/6/1999	1.9	4	0.56	< 0.05
6905725	3/31/1999	2.4		0.54	E 0.04
6905725	4/21/1999	8.4		0.98	0.11
6905725	6/23/1999	0.54	47	0.89	0.09
6905725	10/25/1999	0.01			0.07
6905725	11/30/1999	0.01	11		0.05
6905725	12/20/1999	0.1			< 0.05
6905725	1/24/2000	0.1	24		0.05

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6905725	4/20/2000	0.16			0.07
6905725	5/11/2000	0.07	< 10		0.07
6905725	6/14/2000	8.3		3.3	0.44
6905725	6/15/2000	7.3		2.7	0.25
6905725	6/20/2000	0.22		1.9	0.11
6905725	7/27/2000	0	10		E 0.04
6905725	10/25/2000	0.03			0.28
6905725	11/15/2000	0.1	< 10		0.08
6905725	12/20/2000	0.02			0.06
6905725	1/24/2001	0.24	10	4.3	0.17
6905725	2/14/2001	59		3.2	0.42
6905725	3/28/2001	4.3		2.2	0.12
6905725	4/25/2001	4.1			0.12
6905725	5/22/2001	1.1		1.1	0.08
6905725	5/23/2001	0.82	11	1.1	0.08
6905725	6/18/2001	7.6		1.4	0.21
6905725	6/28/2001	2.5			0.11
6905725	7/26/2001	4.8	228	4.7	0.4
6905725	8/9/2001	0.13		E 1.1	0.1
6905725	9/11/2001	0.03		E 1.1	0.1
6905725	10/24/2001	3.5	50	2.4	0.42
6905725	11/29/2001	0.17	< 10		E 0.06
6905725	12/13/2001	0.83	20		E 0.05
6905725	1/9/2002	0.2	10	0.97	E 0.05
6905725	2/28/2002	1.4	18	1.4	0.09
6905725	3/20/2002	0.97	< 10		E 0.04
6905725	4/18/2002	1.6	17		0.07
6905725	5/22/2002	2.2	20		0.12
6905725	6/27/2002	0.06	10	E 0.69	E 0.04
6905725	8/22/2002	0.17	22	E 0.77	0.08
6905725	2/21/2003	0.05	< 10	1.7	0.15
6905725	3/13/2003	2.5	37		0.2
6905725	3/19/2003	0.3	14	E 1.7	0.14
6905725	4/24/2003	0.19	26	1.9	0.1
6905725	4/30/2003	1.9	32	2.2	0.2
6905725	5/7/2003	2.5	44	2.1	0.23
6905725	6/12/2003	0.72	16	E 1.2	0.09
6905725	7/9/2003	E 0.00	11		0.1
6905725	9/17/2003	0.33	15	1.7	0.14
6905725	11/19/2003	E 0.01	38		0.27
6905725	12/11/2003	7.9	84	5	0.41
6905725	1/8/2004	0.24	19	2.1	0.17
6905725	2/20/2004	41	81	3.5	0.52
6905725	3/17/2004	25	60	1.8	0.18
6905725	4/21/2004	1.6	15		0.06

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6905725	5/12/2004	0.55	< 10		0.07
6905725	6/24/2004	1.9	31	1.6	0.21
6905725	7/13/2004	11	52	1.6	0.21
6905725	8/24/2004	0.25	21	1.1	0.07
6905725	9/15/2004	0.52	< 10	E 1.1	0.09
6905725	10/28/2004	2	< 10		0.14
6905725	11/17/2004	1.8	< 10	0.67	0.06
6905725	12/17/2004	2.4	< 10	0.71	0.05
6905725	1/26/2005	18	46	1.8	0.22
6905725	2/8/2005	22	65	2.6	0.18
6905725	3/17/2005	2.9	< 10		0.13
6905725	4/7/2005	2.9	< 10		0.06
6905725	5/11/2005	11	10		0.07
6905725	6/29/2005	1.7	21		0.08
6905725	7/14/2005	0.02	< 10		0.04
6905725	8/18/2005	0.08	22	E 1.8	0.12
6905725	9/21/2005	0.05	74		0.23
6905725	10/4/2005	0.9	316	4.2	0.59
6905725	11/1/2005	0.04	22		0.16
6905725	12/13/2005	0.01	< 10		0.06
6905725	1/27/2006	0.12	< 10		0.05
6905725	2/15/2006	0.17	15	2.9	0.07
6905725	3/9/2006	0.3	< 10		0.04
6905725	4/14/2006	1.3	18		0.08
6905725	5/12/2006	1.1	10		0.07
6905725	6/15/2006	0.11	< 10		0.06
6905725	7/17/2006	0	34	1.5	0.15
6905725	8/8/2006	2.4	203	1.9	0.36
6905725	9/21/2006	0.06	11	1.1	0.06
6905725	10/23/2006	0.03	20	2.1	0.14
6905725	11/15/2006	0.03	82		0.2
6905725	12/15/2006	0.2	< 10	0.95	0.1
6905725	1/24/2007	0.62	11	1	0.1
6905725	2/22/2007	8	< 10	4.4	0.58
6905725	3/13/2007	6.5	25	2.3	0.17
6905725	4/24/2007	1.7	< 50		0.08
6905725	5/8/2007	74	176	2	0.36
6905725	6/28/2007	12	444	5.6	0.6
6905725	7/17/2007	0.06	26		0.08
6905725	8/22/2007	2.5	245	3.5	0.53
6905725	9/26/2007	0.04	54		0.18
6905725	10/17/2007	0.07	312	1.9	0.37
6905725	11/7/2007	0.05	11		0.16
6905725	12/18/2007	2.8	20	2.5	0.2
6905725	1/9/2008	40	68	3.1	0.28

USGS Gage Number	Sample Date	Flow (cfs)	NFR (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
6905725	2/26/2008	39	180	3.1	0.57
6905725	3/25/2008	6.2	21	1.4	0.1
6905725	4/17/2008	5.8	28	1.1	0.11
6905725	5/22/2008	1.2	10		0.07
6905725	6/19/2008	2.5	25	1.5	0.15
6905725	7/18/2008	0.4	16		0.1
6905725	8/14/2008	3.9	182	1.9	0.28
6905725	9/23/2008	2.1	14		0.12
6905725	10/28/2008	1.5	< 15	1.3	0.12
6905725	11/20/2008	4.8	< 15	1.3	0.1
6905725	12/4/2008	3.5	< 15	0.6	0.05
6905725	1/29/2009	0.89	< 15	0.62	0.06
6905725	2/26/2009	4.8	< 15	0.62	0.05
6905725	3/12/2009	25	170	2.3	0.28
6905725	4/23/2009	5.4	< 15	E 0.64	0.07
6905725	5/14/2009	47	214	2.4	0.34
6905725	6/26/2009	5	< 150	1.8	0.16
6905725	7/21/2009	0.32	< 15		0.05
6905725	8/19/2009	2	106	2.1	0.23

NOTE: Where data are estimated (E) the estimate was used. Where data was less than the limit of detection [<] a value one half the limit of detection was used.

Appendix C
Development of Suspended Solids Targets Using Reference Load Duration Curves

Overview

This procedure is used when a lotic[13] system is placed on the 303(d) List for a pollutant and the designated use being addressed is aquatic life. In cases where pollutant data for the impaired stream is not available a reference approach is used. The target for pollutant loading is the 25th percentile calculated from all data available within the ecological drainage unit (EDU) in which the water body is located. Additionally, it is also unlikely that a flow record for the impaired stream is available. If this is the case, a synthetic flow record is needed. In order to develop a synthetic flow record calculate an average of the log discharge per square mile of USGS gaged rivers for which the drainage area is entirely contained within the EDU. From this synthetic record develop a flow duration from which to build a load duration curve for the pollutant within the EDU.

From this population of load durations follow the reference method used in setting nutrient targets in lakes and reservoirs. In this methodology the average concentration of either the 75th percentile of reference lakes or the 25th percentile of all lakes in the region is targeted in the TMDL. For most cases available pollutant data for reference streams is also not likely to be available. Therefore follow the alternative method and target the 25th percentile of load duration of the available data within the EDU as the TMDL load duration curve. During periods of low flow the actual pollutant concentration may be more important than load. To account for this during periods of low flow the load duration curve uses the 25th percentile of EDU concentration at flows where surface runoff is less than 1 percent of the stream flow. This result in an inflection point in the curve below which the TMDL is calculated using load calculated with this reference concentration.

Methodology

The first step in this procedure is to locate available pollutant data within the EDU of interest. These data along with the instantaneous flow measurement taken at the time of sample collection for the specific date are recorded to create the population from which to develop the load duration. Both the date and pollutant concentration are needed in order to match the measured data to the synthetic EDU flow record.

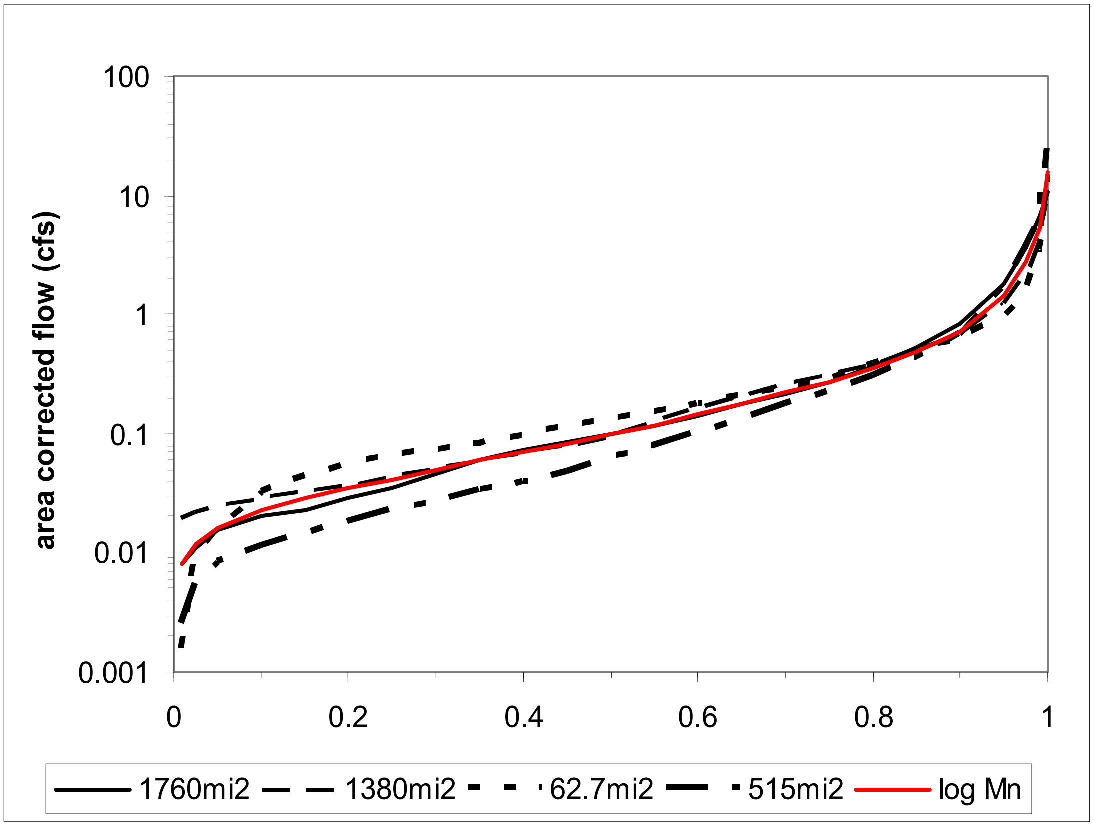
Secondly, collect average daily flow data for gages with a variety of drainage areas for a period of time to cover the pollutant record. From these flow records normalize the flow to a per square mile basis. Average the log transformations of the average daily discharge for each day in the period of record. For each gage record used to build this synthetic flow record calculate the Nash-Sutcliffe statistic to determine if the relationship is valid for each record. This relationship must be valid in order to use this methodology. This new synthetic record of flow per square

[13] Lotic = pertaining to moving water

mile is used to develop the load duration for the EDU. The flow record should be of sufficient length to be able to calculate percentiles of flow.

The following examples show the application of the approach to one Missouri EDU.

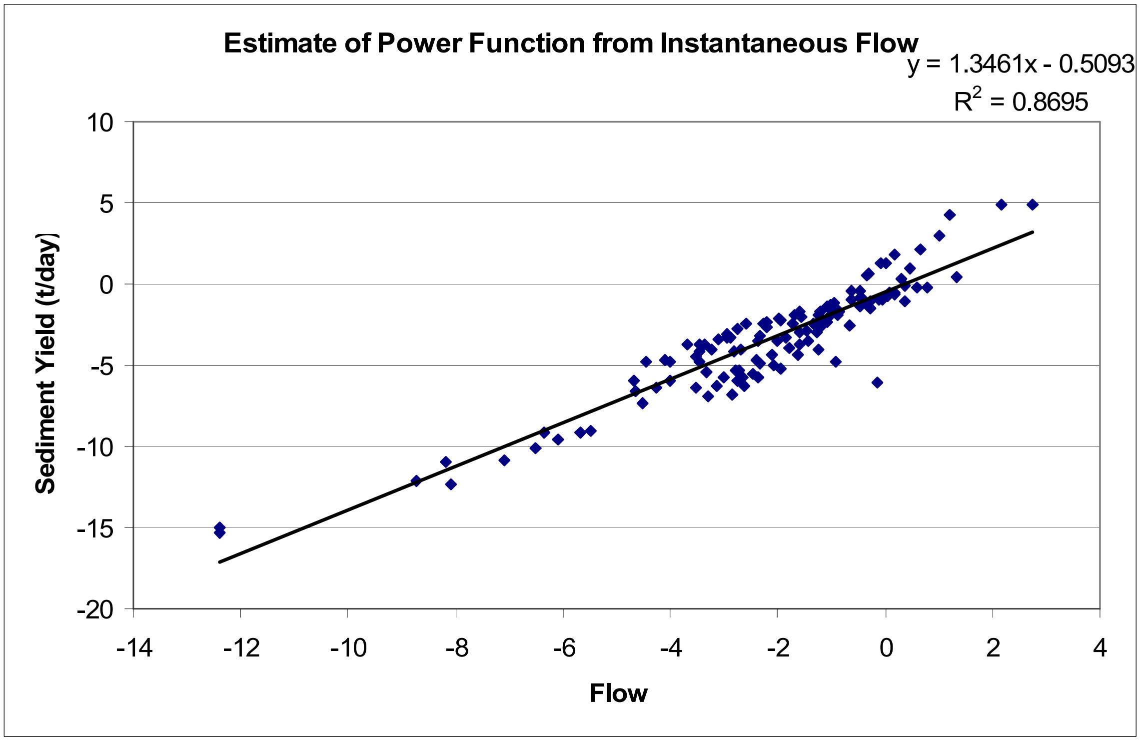
The watershed-size normalized data for the individual gages in the EDU were calculated and compared to a pooled data set including all of the gages. The results of this analysis are displayed in the following figure and table:



Gage	gage	area (mi^2)	normal Nash-Sutcliffe	lognormal Nash-Sutcliffe
Platte River	06820500	1760	80%	99%
Nodaway River	06817700	1380	90%	96%
Squaw Creek	06815575	62.7	86%	95%
102 River	06819500	515	99%	96%

This demonstrates the pooled data set can confidently be used as a surrogate for the EDU analyses.

The next step is to calculate pollutant-discharge relationships for the EDU, these are log transformed data for the yield (tons/mi^2/day) and the instantaneous flow (cfs/mi^2.) The following graph shows the EDU relationship:



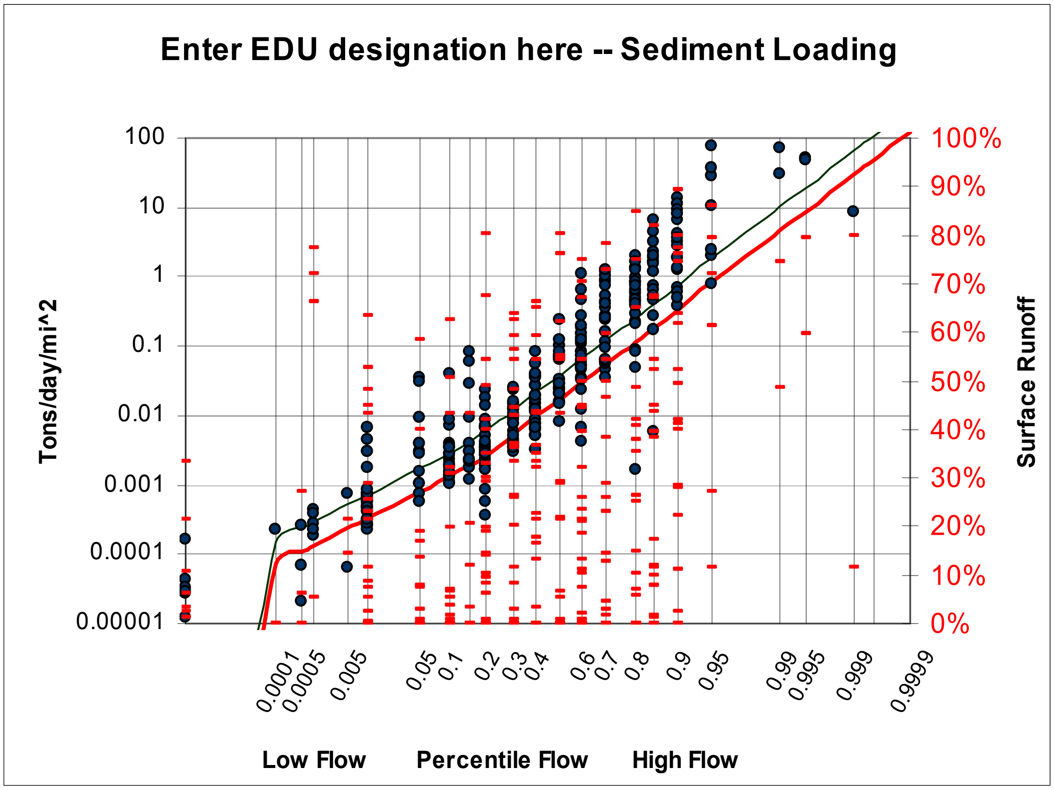
Further statistical analyses on this relationship are included in the following Table:

m	1.34608498	b	-0.509320019
Standard Error (m)	0.04721684	Standard Error (b)	0.152201589
r^2	0.86948229	Standard Error (y)	1.269553159
F	812.739077	DF	122
SSreg	1309.94458	SSres	196.6353573

The standard error of y was used to estimate the 25 percentile level for the TMDL line. This was done by adjusting the intercept (b) by subtracting the product of the one-sided Z_{75} statistic times the standard error of (y). The resulting TMDL Equation is the following:

*Sediment yield (t/day/mi^2) = exp (1.34608498 * ln (flow) - 1.36627)*

A resulting pooled TMDL of all data in the watershed is shown in the following graph:



To apply this process to a specific watershed would entail using the individual watershed data compared to the above TMDL curve that has been multiplied by the watershed area. Data from the impaired segment is then plotted as a load (tons/day) for the y-axis and as the percentile of flow for the EDU on the day the sample was taken for the x-axis.